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HARDNESS, STRENGTH AND ELONGATION CORRELATIONS FOR SOME TITANIUM-BASE ALLOYS

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Westinghouse Electric Corporation

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Rockwell hardness and tensile data obtained in an earlier study on three titanium base alloys (Ti-13V-11Cr-3Al, Ti-5Al-2.5Sn and Ti-6Al-4V) have been augmented with Meyer, Vickers and Knoop hardness measurements. The tensile data have been analyzed to give the work hardening coefficient n and this has been correlated with (a) the ratios of both yield stress σ_y and ultimate tensile stress σ_u to Vickers hardness H_V; (b) the Meyer hardness coefficient m; and (c) uniform elongation. The correlations involving (a) and (b) above did not follow the expected behavior.

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FOREWORD

This report was prepared by the Westinghouse Electric Corporation, Astronuclear Laboratory, Pittsburgh, Pennsylvania, under U.S.A.F. Contract F33615-71-C-1163. The contract was initiated under Project No. 7351 "Metallic Materials", Task No. 735108, "Processing of Metals", and was administered under the direction of the Air Force Materials Laboratory, Wright-Patterson Air Force Base, Ohio with Mr. A. M. Adair and Mr. V. DePierre (AFML/LLM) as Air Force Project Engineers.

This report discusses research conducted from 1 November 1971 to 15 March 1972. It was submitted by the authors on 28 February 1973.

This Technical Report has been reviewed and is approved.

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Previously published results on aluminum-base alloys and steels showed that accurate prediction of yield stress and ultimate tensile stress was possible from hardness data. The present study was undertaken to see if the relationships were also obeyed by titanium-base alloys. The intention was to permit exploitation of the economic advantages which would result from a saving in machining cost and in testing time, if the judicious use of hardness testing were to provide data approximately equivalent to that obtained by tensile testing.

Rockwell hardness and tensile data obtained in an earlier study on three titanium base alloys (Ti-13V-11Cr-3Al, Ti-5Al-2.5Sn and Ti-6Al-4V) have been augmented with Meyer, Vickers and Knoop hardness measurements. The tensile data have been analyzed to give the work hardening coefficient n and this has been correlated with (a) the ratios of both yield stress σ_y and ultimate tensile stress σ_u to Vickers hardness H_v; (b) the Meyer hardness coefficient m; and (c) uniform elongation. The correlations involving (a) and (b) above did not follow the expected behavior.

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I INTRODUCTION

Indentation hardness testing provides a simple technique for following changes in strength resulting from metal processing. However, due to the complexity of the deformation around an indentation, no universal linear conversion exists relating a single hardness value to either yield strength or ultimate tensile strength. Tabor[1] has derived a single conversion factor, but the flow stress estimate obtained is that appropriate to about 8% engineering strain; hence the conversion is of limited value. More complex formulae[1,2], although somewhat unwieldy, have application where tensile data are required, but where tensile testing is impossible, impractical or undesirable. Typical applications for these formulae might include room temperature testing of hot-torsion tested rods in the laboratory or the non-destructive estimation of the strength of castings, since in these situations tensile testing would be impossible. A further use would be for laboratory tests where economy of time or material are required such as in screening tests in studies of the effects of process variables on mechanical properties. It was this latter application, with a view to achieving cost savings, which prompted the present investigation.

In a tensile test, not only is information obtained about strength, but also about elongation. While it appears that hardness testing cannot differentiate between brittle and ductile metals, it has been suggested that an indication of ductility can be obtained, in some cases, in the form of an estimate of uniform elongation[3,4]. The present study was undertaken to check if expected strength/hardness/ductility relationships were obeyed for titanium base alloys. A beta alloy (Ti-13V-11Cr-3Al), an alpha alloy (Ti-5Al-2.5Sn) and an alpha-beta alloy (Ti-6Al-4V) were evaluated.

1.1. Stress/Hardness Relations

Tabor[1] has shown that, for steel and a variety of other metals, the ratio of the UTS σ_u to the Vickers hardness H_v is given by

$$\frac{\sigma_u}{H_v} = \frac{(1-n)}{2.9} \left[\frac{12.5n}{1-n}\right]^n \qquad (1)$$

where n is the work hardening coefficient. The latter quantity is obtained from the slope of a log-log plot of true stress σ vs. true strain ε, as implied in the relation

$$\sigma = K\varepsilon^n \qquad (2)$$

where both K and n are constants. Tabor suggested that, while a numerical factor of 2.9 in. Eq. 1 was appropriate to steel, a value of 3.0 applied to copper. Cahoon et al.[2] maintained that a numerical factor of 3.0 was appropriate to steel, brass and aluminum, i.e.,

$$\frac{\sigma_u}{H_v} = \frac{(1-n)}{3.0} \left[\frac{12.5n}{1-n}\right]^n \tag{3}$$

It should be noted that Eqs. 1 and 3 relate hardness to ultimate tensile stress. However, a relationship between the yield stress σ_y and Vickers hardness H_v has been given by Cahoon et al.[2]

$$\frac{\sigma_y}{H_v} = \frac{(0.1)^n}{3.0} \tag{4}$$

Taking logarithms gives

$$\log(\sigma_y/H_v) = -n - \log 3.0 \tag{5}$$

As this relationship has been applied successfully to a variety of materials, including aluminum alloys and some steels[2], it may have universal application. If so, then different materials, each with a range of values of the work hardening coefficient n, should all give data lying on the same straight line, of slope - 1 and intercept - log 3.0 on the log (σ_y/H_v) axis, when plotted according to Eq. 5.

Where stress-strain data are not available, the work hardening coefficient may usually be estimated from the equation

$$n = (m-2) \tag{6}$$

where m is the Meyer hardness coefficient. Eq. 6 has been shown to be true theoretically, and its validity has been demonstrated for a variety of materials[1]. The quantity m is obtained as the slope of a log-log graph of load W vs. indentation diameter δ for a spherical indenter. These quantities are related by the equation

$$W = K'\delta^m \tag{7}$$

where K' and m are constants.

The relationships given in Eqs. 1, 3 and 5 are depicted in Fig. 1 where the range of n values covers that from hardened ($n < 0.1$) to fully annealed ($n \approx 0.5$) materials. The corresponding range of m values, according to Eq. 6, is also shown. Thus it should be possible, by suitable analysis of a series of hardness indentations, to estimate both yield stress and UTS.

1.2. Derivation of Stress-Strain Curves from Hardness Data

According to equations given by Tabor[1], points along a stress-strain curve may be estimated by evaluation of equivalent stress and strain for a series of indentations made at different loads with a spherical indenter. The relevant equations are

$$\sigma = H_m/2.8 = (4W/\pi D^2)/2.8 \qquad (8)$$

$$\varepsilon = 0.2\delta/D \qquad (9)$$

where σ and ε are the stress and strain estimates for a Meyer hardness H_m; δ is the diameter of the indentation produced by a ball of diameter D under an applied load W. Application of these two equations will be discussed in more detail later.

1.3. Estimation of Ductility from Hardness Data

One further relationship is worthy of note, since it may provide a means of estimating uniform elongation from hardness measurements[4]. For metals which obey Eq. 2, it has been shown that the true strain to the ultimate tensile load should be numerically equal to the work hardening coefficient[5], i.e.

$$\varepsilon_u = n \qquad (10)^*$$

Here ε_u is the total (i.e. elastic plus plastic) strain occuring during stable flow, before the load instability of necking. Incorporation of Eq. 6 gives

$$\varepsilon_u = (m - 2) \qquad (11)$$

which suggests that estimation of uniform elongation from hardness data is possible. The application of this equation will be considered in greater detail later. In an alternative method due to Böklen[3], uniform elongation is correlated with the height of the material piled up around an indentation. However, this technique is not considered further in the present work.

* The derivation of this relationship is given in Appendix 1.
It is of interest to note that a similar equation involving the equivalent engineering strain e_u has been given by Tabor[1] viz., $e_u = n/(1-n)$.

II EXPERIMENTAL

The alloys used in this study were the subject of an earlier investigation[6]. In that study, three titanium-base alloys were extruded at a range of temperatures and either cooled in air or water quenched. The extruded material was then subjected to an aging treatment, Table I. A tensile specimen was machined from a piece of each bar and Rockwell hardness readings made on an adjacent piece. In the present study, additional hardness readings were obtained and the tensile load-elongation curves were subjected to further analysis.

Four types of hardness measurement were carried out, normally on transverse sections:

1) A range of loads was used for Brinell tests with a steel ball on a Vickers hardness testing machine. The data obtained were used (a) to estimate equivalent stress and strain, as outlined above, and (b) to fit to Meyer's Law, Eq. 7, in order to determine m. According to Tabor[7], the minimum load required to give fully plastic deformation, so that Eq. 7 is obeyed, can be estimated from a knowledge of the elastic properties of the specimen and the ball indenter, and the yield stress of the former. For the 1-mm ball used in the present study, these approximate lower limits were 21, 11 and 15 kg. for the Ti-13V-11Cr-3Al, Ti-5Al-2.5Sn and Ti-6Al-4V alloys respectively. A load range from 40 to 120 kg was therefore used; from this data, a series of values of both Meyer and Brinell* hardness was determined. Log-log plots were drawn up according to Eq. 7 and values of the slope m were determined. Additional readings were made with applied loads of 5, 10 and 20 kg. Data from the four lowest loads then gave appropriate equivalent strains, according to Eq. 9, for comparison of the actual flow stresses with those estimated from Eq. 8.

2) Additional Rockwell hardness readings were made using a 1/16 inch diameter ball indenter and standard loads of the F, B and G scales, i.e. 60, 100 and 150 kg. Supplementary weights were also used, and further non-standard hardness readings taken corresponding to 72.5, 85, 112.5 and 125 kg. loads. Attempts to obtain straight lines on log-log plots, in order to derive a parameter analogous to the Meyer hardness coefficient, proved unsuccessful. Among the plots tried were log (load) vs. log (100-hardness) and log (100 kg + load) vs. log (100-hardness). However, none of the graphs gave satisfactory straight lines.

3) Vickers hardness tests were performed using a 100 kg. load. Three indentations were made on each specimen.

4) In order to try to detect the presence of anisotropy of hardness, and therefore of strength, Knoop hardness tests were performed with the long diagonal lying both parallel and transverse to the axis of the extrusion. However, there were no significant or systematic differences in the hardness values obtained in the two directions.

* Since tables were not available for a 1-mm ball and loads of 40, 60, 80, 100 and 120 kg., hardness was evaluated by means of a simple computer program. This program and the data generated are given in Appendix 3.

Tensile load and displacement data from the earlier study[6] were converted to true stress and true strain by reading the co-ordinates of a series of points, and processing the data by computer. Since the chart record showed machine crosshead displacement, only the plastic strain could be derived directly from the data.# An estimate of elastic strain was made using a value of Young's Modulus = 16.5×10^6 psi (1.14×10^5 Nm^{-2}), and this was added to the plastic strain to obtain "total corrected strain".# The logarithm of this quantity was used in the log (true stress) vs. log (true strain) plots to determine the work hardening coefficient, n.

The simple computer programs, and the data output, are given in Appendices 4 and 5.

III RESULTS

3.1. Stress/Hardness Ratios and Work Hardening Rates

Analysis of the experimental data showed that several of the relationships obeyed by other materials did not apply to the Ti-base alloys in the present study. Typical of the anomalous behavior is the lack of correlation between the Meyer hardness coefficient m and the work hardening coefficient n (Table II). Instead of fitting Eq. 6, the data for the beta-alloy show an approximately constant value of n over a range of m values, while the converse is true for the other two alloys. The discrepancy between the observed and the predicted behavior results from a difference in the deformation conditions in a tensile and a hardness test, and may be attributable to a difference in deformation mechanism, as suggested by Lenhart[8] for Mg and some Mg-base alloys. In his study, Lenhart observed deformation twins on the faces of the hardness indentations. In the present work, twins were not observed. However, features resembling twins were seen on the faces of some indentations. They were attributed to defects on the surface of the ball indenter since they occurred in corresponding locations in all indentations, Fig. 2.

Values of yield and ultimate tensile stresses, hardness and ratios of stress to hardness are given in Table II. The correlation of the ratios σ_y/H_v and σ_u/H_v with the work hardening coefficient n also did not follow the expected trend of Fig. 1; the experimental data, presented in Fig. 3, show considerable deviation from the predicted lines. For the beta alloy, the points all occur at similar values of n and show a wide spread of values of σ_y/H_v and σ_u/H_v.

While the spread of the data in Fig. 3 is considerable, deviations from the predicted straight line representing the yield stress/hardness ratio can be rationalized if the data are considered according the structure present during the extrusion pre-heat (see key). The deviations correspond to changes in slope of the predicted line, and would be represented mathematically by changes in Eqs. 4 and 5.

Replotting of the ratios against the Meyer hardness coefficient showed stronger trends, Fig. 4*, although the data did not fit the relationships expected from Eqs. 1, 3 and 5. In view of the poor correlation observed, it is suggested that prediction of yield and ultimate tensile stress from hardness data alone may be possible only for the beta alloy, although a trend is also apparent for the alpha-beta alloy.

* It should be noted that, while a ball indenter is used to obtain data for the Meyer hardness coefficient m, the strength/hardness ratios correlated with m in Fig. 4 involve the use of Vickers hardness values obtained with a pyramid indenter. Brinell hardness is unsuitable for the evaluation of these ratios since it shows some dependence on the size of the indentation, and therefore on the imposed load. This dependence can, however, be used to advantage, as discussed in the next section.

3.2. Comparison of Stress-Strain Curves with Hardness Data

In hardness tests carried out using the ball indenter, a range of loads was used. Therefore, a range of equivalent strain and corresponding stress values could be derived, according to Eqs. 9 and 8 respectively. Agreement between these derived data and the values of true stress, read from stress vs. plastic strain curves, was poor. In every case the converted hardness data fell below the tensile data, and this was more marked in the alpha and alpha-beta alloys than in the beta alloy. Typical data are shown in Fig. 5. Thus, Tabor's claim that hardness provides a reliable measure of the shape of that part of the stress/strain curve which lies within the first 25% of strain[9], is not applicable to the alloys used in the present study. In order to adjust the converted hardness data to be of similar magnitude to the tensile data, the divisors required would be ~ 1.3 for the alpha and alpha-beta alloys and ~ 2.4 for the beta alloy, rather than the 2.8 of Eq. 8*.

3.3. Correlation of Uniform Elongation with m and n.

In order to check the validity of Eqs. 10 and 11, uniform elongation was determined from the chart record and converted to true (plastic) strain. Since the elongation to peak load could not be determined unequivocally, a range of strain was obtained from each chart, as shown in Table II and in Fig. 6a, where the data are plotted against the work hardening coefficient n. More precise determination of the strain to peak load was obtained by the use of Considère's construction which required plots of true stress vs. engineering strain (see Ref. 5)†. The corresponding true strain values are plotted in Fig. 6b. It should be noted that, while the data points refer to plastic strain, Eq. 10 refers to total strain. A correction was therefore made by determining the mean UTS from the data for each alloy and subtracting the corresponding estimated elastic strain to give the dashed lines in Fig. 6. It can be seen that the data fit the predicted relationship reasonably well so that, to a first approximation, Eq. 10 is obeyed. However, the corresponding expression which incorporates the Meyer hardness coefficient m (Eq. 11) did not fit the predicted expression as a consequence of the breakdown of the relationship between m and n (Eq. 6) discussed earlier. As the experimental data showed considerable scatter, no well-defined trends are apparent and no correlation of the two variables is possible. Hence prediction of uniform strain by this method does not appear possible for the three materials studied.

* See Appendix 3 for a listing of these ratios, evaluated for each hardness indentation after applying Eqs. 8 and 9.

† See Appendix 2 for a derivation of the relevant equation.

IV DISCUSSION

4.1. Estimation of Strength from Hardness Data

As the data in Table II and in Fig. 5 show, estimates of stress and strain according to Eqs. 8 and 9 do not give a good approximation to the stress-strain curve obtained in a tensile test, particularly for the alpha and alpha-beta alloys. The origins of the discrepancy, and the consequences of it, merit a closer examination and this will now be presented.

It should be noted that Eqs. 8 and 9 were derived empirically by Tabor[1], although they have been verified by comparison of hardness data with both compressive [1,8] and tensile[8] curves. If the converted hardness data presented in Fig. 5 is re-plotted according to Eq. 2 ($\sigma = K\varepsilon^n$), apparent values of the work hardening coefficient n can be derived. Such an analysis yields values of approximately unity for (b) and (c) and approximately one third for (a). Several points of interest arise from this observation.

i. These apparent values of n do not agree with those derived from the tensile data.

ii. Even for an annealed material, n values greater than approximately 0.5 do not occur. Thus, during hardness indenting, two of the materials in the present study have apparent work hardening coefficients higher than that obtained, even in soft materials, during deformation by slip. This lends support to Lenhart's suggestion[8], mentioned in section 3.1, that a different deformation mechanism is occurring in each type of test. The converted hardness data in Figs. 5b and 5c lie approximately on straight lines which, when extrapolated, pass through the origin. The data are somewhat similar to those of Mote and Dorn[10] who determined that the high rate of work hardening was associated with the occurrence of twinning in magnesium single crystals and bi-crystals tested in tension. It should be noted, too, that in Fig. 5 the converted hardness values all lie below the tensile curves, and this is also consistent with the suggestion that twinning occurred during hardness indenting.

iii. As a consequence of ii above, Eqs. 8 and 9 may not be valid, and the apparent stress and strain derived by their use may not have any physical significance. If this is true, then the precise values of the apparent work hardening coefficient n are not valid, although it is considered likely that, at least qualitatively, their magnitude has some significance.

iv. Eq. 6 ($n = m-2$) is still not obeyed by the new data; while the n values obtained from the tensile curves are too low, the apparent values obtained from the converted hardness data are too high. In the light of iii above, this is not surprising.

v. If the n values corresponding to tensile and hardness testing are different, as suggested above, then this invalidates the derivation of Eqs. 1 and 3 (on Page 107 of Ref. 1) and of Eq. 4 (Ref. 2), both for the alloys in the present study and for other materials which show different work hardening behavior in tension and in hardness tests. The reason for the deviation from the expected behavior in Fig. 3 is therefore apparent.

At the present time, no alternative general hardness/strength convertion relationship is available for the materials which show this anomalous behavior. Instead, specific equations or relationships may be derived for each alloy. Thus, use of the dashed lines in Fig. 4 would permit convertion of hardness data for the beta and possibly the alpha-beta alloy for the limited range of Meyer hardness coefficients covered in the present study. The alternative is to accept a single convertion factor or a linear equation as discussed in section 4.4.

4.2. Variation of Strength and Hardness with Processing Temperature.

Since hardness is commonly used to monitor the influence of processing on mechanical properties, it is instructive to compare hardness values with both yield and ultimate tensile stresses for a range of processing conditions. In Fig. 7, strength and Rockwell hardness data from Gurney and Male[6] are shown plotted against billet pre-heat temperature; Vickers hardness, determined in the present study, is also given. The changes in hardness do not follow the strength changes exactly but show a variation in the ratio of strength to hardness with specimen history. Thus it is clear that a single hardness determination does not necessarily give a reliable measure of strength.

In addition to the variation of the yield stress/hardness ratio with the work hardening coefficient n, a dependence of the data on the structure during processing, and therefore on the room temperature microstructure, is apparent for the Ti-5Al-2.5Sn alloy, Fig. 3. However, the present study provided insufficient data to determine exactly the extent of the deviation from the predicted relationship.

4.3. Uniform Elongation, Work Hardening Coefficient and Meyer Hardness Coefficient.

The experimental data in Figs. 6a and 6b show that Eq. 10, relating uniform strain ε_u and work hardening coefficient, is obeyed. The agreement is, however, only approximate and has been investigated only over a limited range of the work hardening coefficient n. It should be emphasized that the data were all obtained from tensile test curves, and therefore the results cannot be applied to a hardness study alone unless an estimate of n can be obtained from hardness data, i.e. unless Eq. 6 is obeyed. For the three titanium alloys in the present study, the relationship between work hardening coefficient n and Meyer hardness coefficient m of Eq. 6 is not obeyed, as discussed above. Therefore Eq. 11, which depends on it, and which relates ε_u and m, is also not obeyed. The behavior of the present alloys is unusual since Eq. 6 has been shown to be valid for a variety of materials[1,2], including both 65S aluminum alloy and 1040 steel in which a range of strengths was obtained either by cold working or by heat treating[2].

4.4. Comparison with Previous Work.

In Figs. 8a and 8b, the present data are compared with the linear relationships given by Hickey for Ti-base alloys[11]. In each case, the new data show substantial agreement with the earlier results. Almost all the data points lie within the scatter band drawn at ± twice the standard deviation quoted by Hickey. A plot of Vickers hardness vs. Rockwell "C" hardness (not shown) also gave similar agreement with the published work.

In the material used in the present study, in contrast to that investigated by Zarkades[12], no anisotropy was detected by Knoop hardness measurements. This is not surprising since, with the exception of two extrusions which were carried out at 1625°F, the grain structure appeared equiaxed[6]. Such a structure indicates that recrystallization occurred either during or immediately after extrusion, thereby eliminating an elongated hot work grain structure.

In showing deviation from Eq. 8, as discussed earlier, the present results are somewhat similar to those of Lenhart[8] on Mg and Mg-Al alloys. Instead of a divisor of 2.8 in Eq. 8, Lenhart's data would require divisors of $\sim$ 1.5 for Mg and $\sim$ 2 for the alloys, in order to adjust the hardness data to have a similar magnitude to the tensile data. Since the divisors appropriate to the alloys in the present study are $\sim$ 1.3 for the alpha and alpha-beta alloys and $\sim$ 2.4 for the beta alloy*, once again, the materials are weaker during hardness testing than expected from the tensile test results. Lenhart also carried out compression tests and attributed discrepancies between compression, hardness and tension test results to the occurrence of profuse twinning during compression or hardness testing which gave rise to a lower flow stress than that expected from the tensile data. Thus, the most reasonable explanation of the anomalous hardness/stress ratios found in the present study is Lenhart's suggestion of twinning during hardness testing. Since the twins were not detected by optical observation, it is possible that microtwinning occurred. Investigation of this suggestion by thin foil electron microscopy is, however, outside the scope of the present study.

* See Appendix 3.

V CONCLUSIONS

From an analysis of tensile and hardness data for the three titanium-base alloys, Ti-13V-11Cr-3Al, Ti-5Al-2.5Sn and Ti-6Al-4V, the following conclusions can be drawn:

1) A unique correlation between both of the stress/hardness ratios σ_y/H_v and σ_u/H_v and the Meyer hardness coefficient m has been shown to exist for the Ti-13V-11Cr-3Al alloy; the relationships are not those predicted by the theoretical formulation of Tabor or Cahoon, but do permit the estimations of σ_y and σ_u from hardness data for this alloy.

2) Uniform elongation in tension was found to be approximately equal to the work hardening coefficient n; however, it did not correlate well with m. The expected relationship between m and n, viz $n=(m-2)$ was not obeyed by any of the alloys.

3) The breakdown of the m-n relationship is attributed to a difference in deformation mechanisms operating during tensile and hardness testing. While micro-twins probably formed during hardness indenting, they were not observed in the present study.

4) As a consequence of 3 above, relationships involving stress/hardness ratios did not hold for the alloys in the present study. Thus, the equation given by Tabor relating σ_u/H_v and n is not followed by any of the alloys studied. Data for the Ti-5Al-2.5Sn and Ti-6Al-4V alloys show considerable scatter around the σ_y/H_v vs. n relation proposed by Cahoon et al.; for the limited range of n values studied, the discrepancies between predicted and actual σ_y/H_v values are 5 to 10% and the values appear to show some dependence on the nature of the microstructure.

5) As a further consequence of 3 above, points along the stress-strain curve, estimated from a series of Meyer hardness readings determined at different loads, for true strains of about 4% to 10%, showed moderately good agreement only for the Ti-13V-11Cr-3Al alloy. The relevant equations were not followed by the other two alloys.

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TABLE I

Post-Extrusion Heat Treatments[6]

Alloy	Treatment
Ti-5Al-2.5Sn	1 hr. at 1000°F, air cool.
Ti-6Al-4V	4 hrs. at 1000°F, air cool.
Ti-13V-11Cr-3Al	24 hrs. at 900°F, air cool.

TABLE II

Stress, Strain and Hardness Data

Composition* wt.%	Extrusion* Number	Billet* Preneat Temp. °F	Yield* Stress ksi	UTS* ksi	Rockwell* "C" Hardness	Vickers Hardness H_v kg mm^{-2}	σ_y/H_v (dimen-sionless)	σ_u/H_v (dimen-sionless)	Work# Hardening Coeff. n	Meyer+ Hardness Coeff. m	Mean H_m/σ_p	Uniform Plastic Strain: Direct From Chart	Uniform Plastic Strain: By Considère's Construction
Ti-13.8%V-	3375	1675	172.1	190.8	40.0	384	0.316	0.350	0.093	2.08	2.39	0.025-0.080	0.060
11.2%Cr-	3303	1750	163.6	183.5	40.3	397	0.290	0.325	0.088	2.27	2.57	0.035-0.085	0.065
-3.1%Al	3272	1900	159.9	179.8	39.0	371	0.304	0.341	0.086	2.18	2.36	0.040-0.086	0.040
(water	3385	2050	164.9	184.3	37.0	387	0.300	0.335	0.092	2.17	2.43	0.035-0.080	0.070
quenched	3260	2150				382				2.13			
after	3331	2250	161.8	180.7	38.8	393	0.290	0.324	0.094	2.23	2.56	0.040-0.060	0.070
extrusion)													
Ti-5.1%Al-	3246	1625	131.3	135.0	29.8	311	0.297	0.305	0.060	2.30	1.37	0.040-0.077	0.060
2.2%Sn	3174	1725	129.1	131.1	31.8	318	0.286	0.290	0.082	2.25	1.38	0.050-0.089	0.045
(water	3239	1825	121.2	129.8	30.5	312	0.273	0.293	0.074	2.25	1.38	0.044-0.093	0.065
quenched	3241	1860	131.4	137.4	31.8	328	0.282	0.295	0.064	2.26	1.20	0.025-0.065	0.045
after	3167	1900	127.7	134.8	31.5	333	0.270	0.285	0.060	2.27	1.22	0.048-0.076	0.035
extrusion)	3243	1940	126.2	132.5	32.8	323	0.275	0.289	0.066	2.20	1.22	0.020-0.073	0.055
	3234	2100	124.7	130.1	32.3	329	0.267	0.278	0.053	2.25	1.26	0.025-0.055	0.050
Ti-6.4%Al-	3247	1625	155.5	156.5	34.8	345	0.317	0.319		2.38			
4.1%V	3475	1775	142.1	153.8	34.8	346	0.289	0.304	0.066	2.31	1.40	0.025-0.095	0.060
(air cooled	3481	1825	142.5	154.8	35.8	356	0.282	0.306	0.085	2.30	1.45	0.041-0.085	0.055
after	3169	1900	135.9	147.6	36.3	359	0.266	0.289	0.055	2.29	1.19	0.020-0.075	0.045
extrusion)	3235	2100	137.3	149.5	32.8	357	0.271	0.295	0.072	2.24	1.50	0.020-0.097	0.040

Note: 1 ksi = 6.895 x 10^6 Nm^{-2}
1 kg mm^{-2} = 9.807 x 10^6 Nm^{-2}

* Data from Ref. 6.
\# Evaluated from chart data which was converted to true stress and true strain and plotted according to the logarithmic form of Eq. 2.
\+ Evaluated from hardness data plotted according to the logarithmic form of Eq. 7.

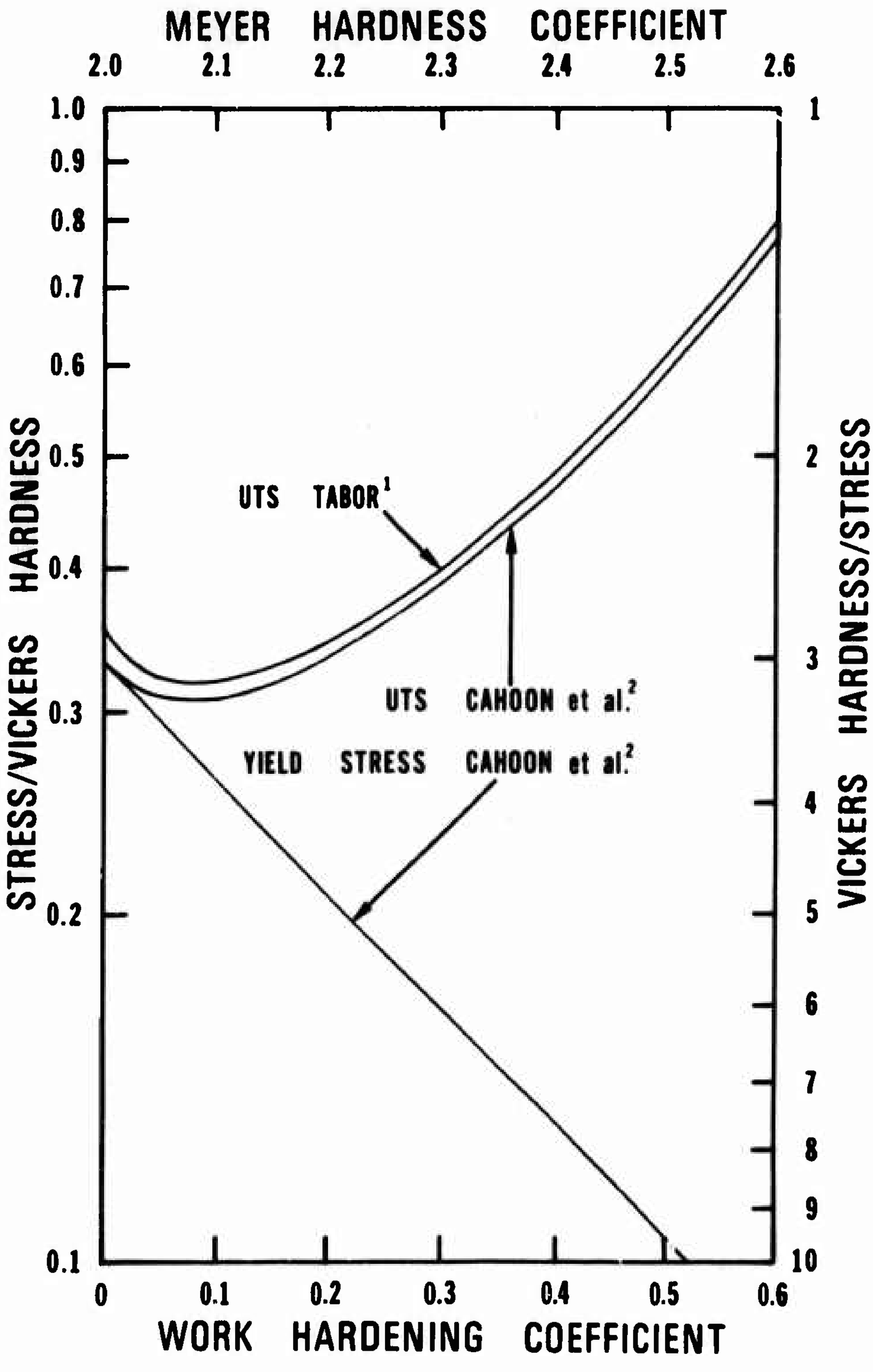

Figure 1. Predicted relationships between the stress/Vickers hardness ratio, the work hardening coefficient, and the Meyer hardness coefficient according to Eqs. 1, 3, 5 and 6.

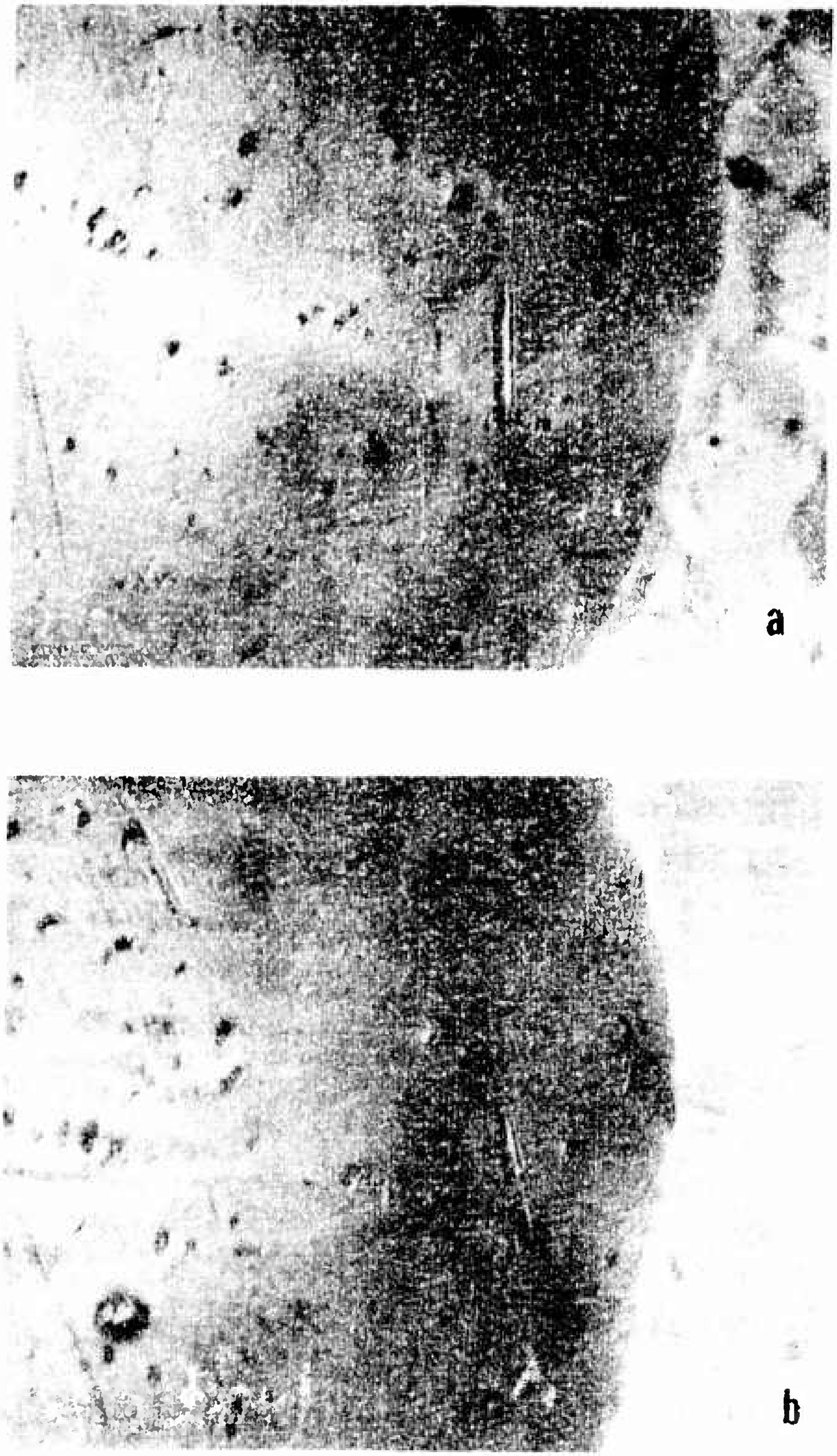

Figure 2. Indentations made with a 2mm diameter ball in two of the alloys, showing the occurrence of artefacts similar in appearance to deformation twins. (a) Ti-13V-11Cr-3Al; (b) Ti-5Al-2.5Sn. x300

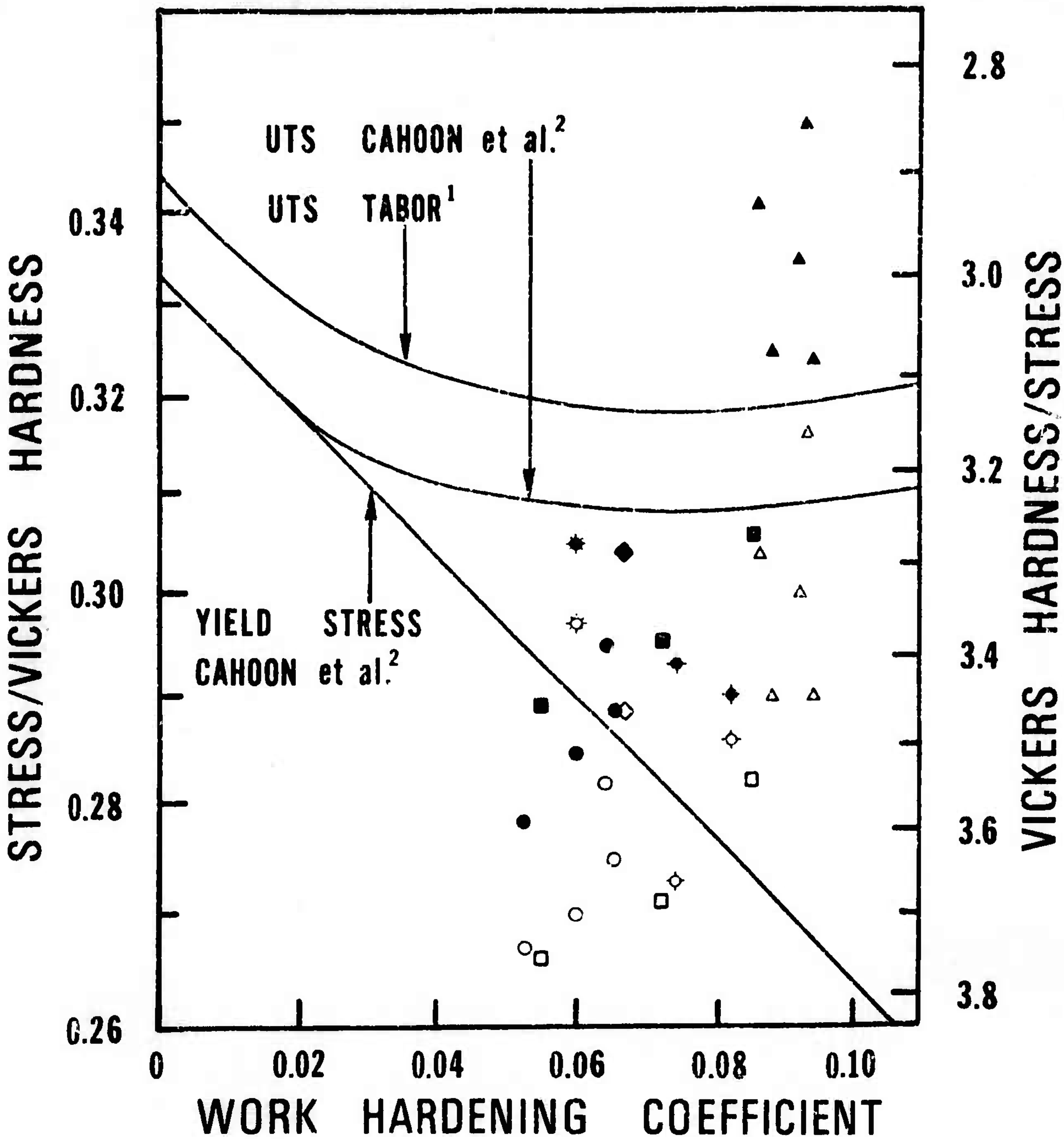

Figure 3. Experimental stress/Vickers hardness ratios as a function of work hardening coefficient. The relationships predicted by Eqs. 1, 3 and 5 are shown. (For key to data symbols, see pg. 18).

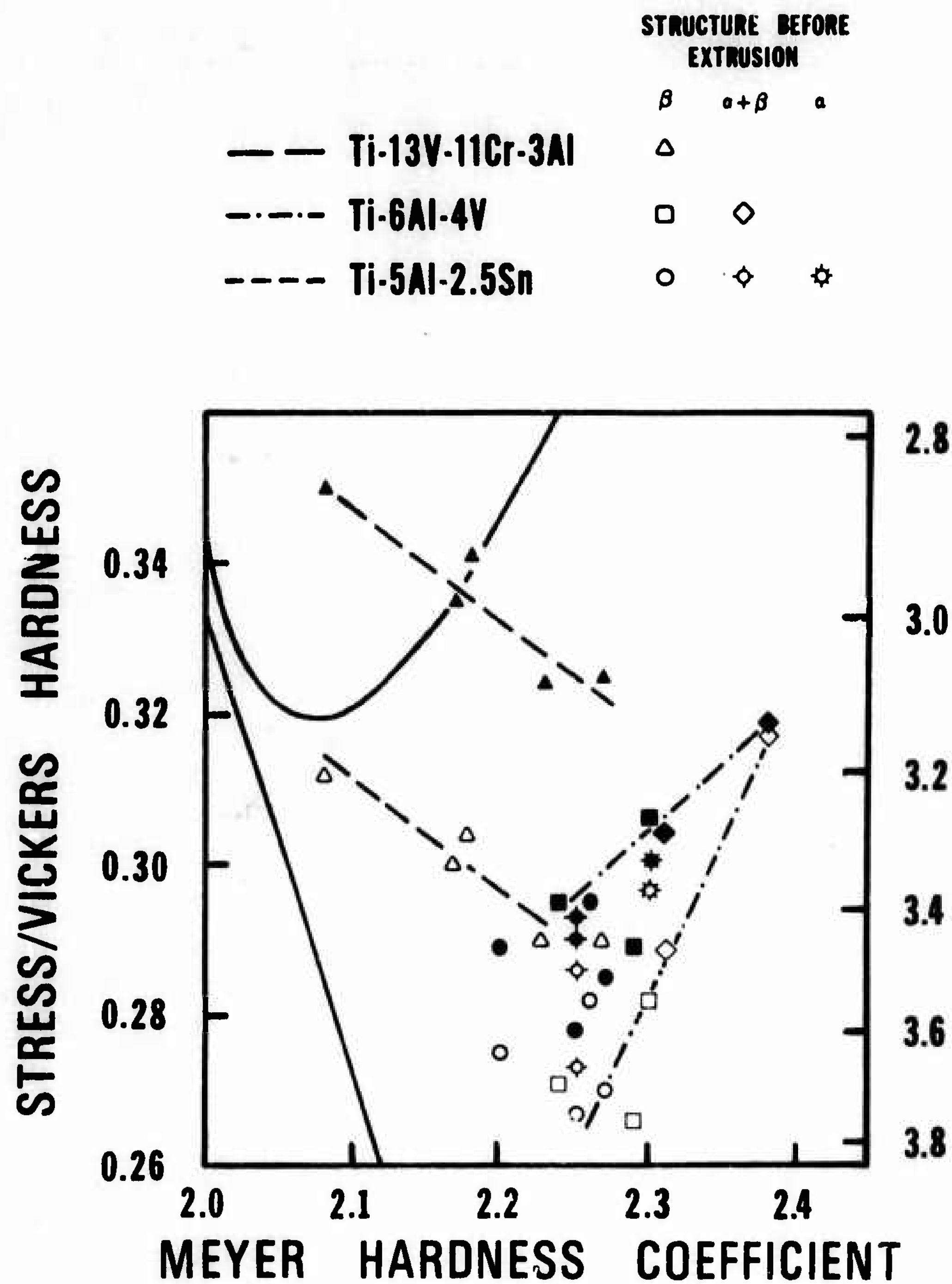

Figure 4. Experimental stress/Vickers hardness ratios as a function of Meyer hardness coefficient. The full lines indicate the relationships predicted by combining Eqs. 1 and 5, in turn, with Eq. 6. The filled symbols are for UTS/hardness and the open symbols are for yield stress/hardness. The key identifies the symbols used in Figs. 3 through 8.

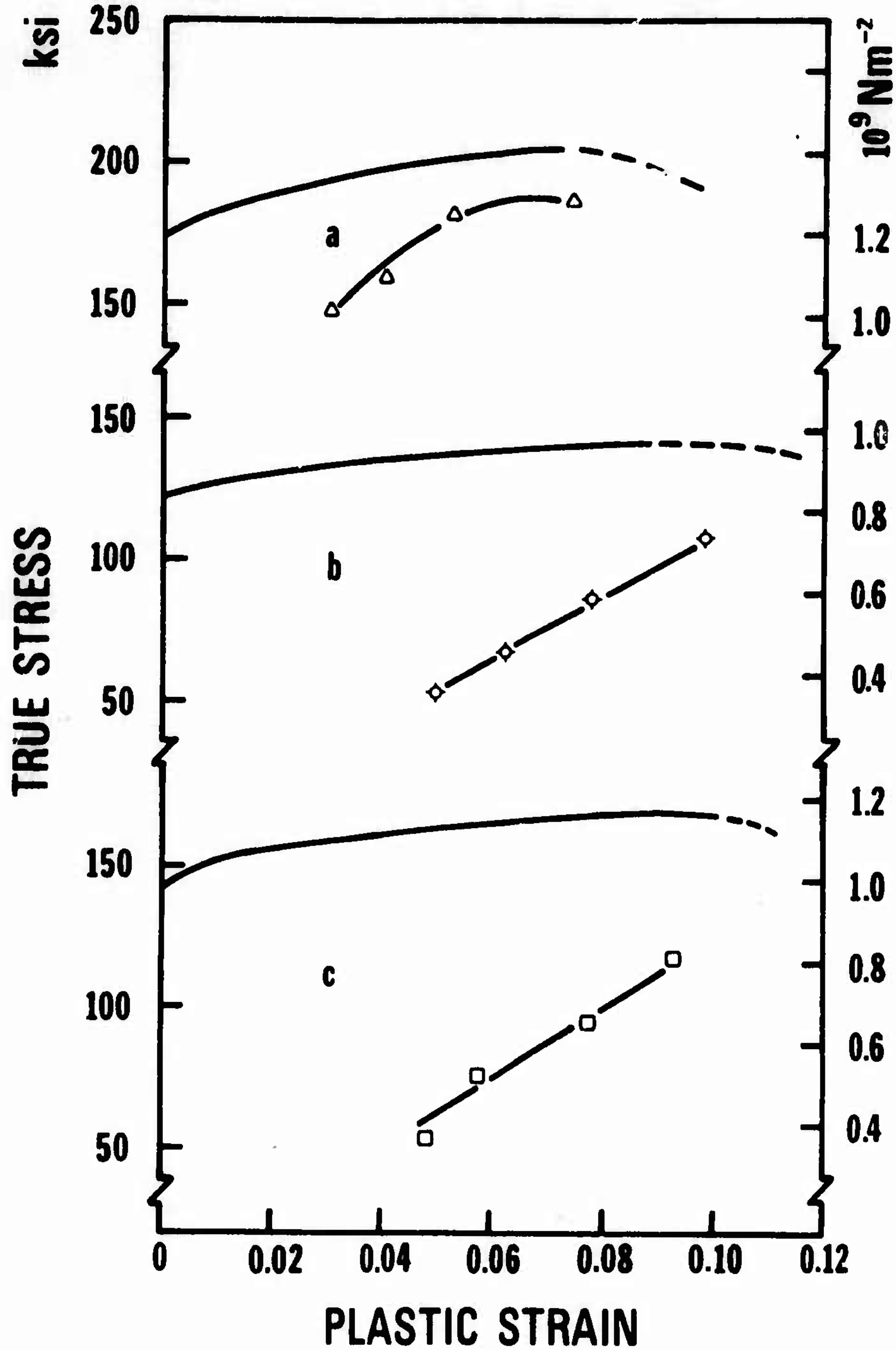

Figure 5. Comparison of true stress-true plastic strain curves with converted Meyer hardness data plotted according to Eqs. 8 and 9 for a typical specimen of each alloy:
(a) Ti-13V-11Cr-3Al (3375)
(b) Ti-5Al-2.5Sn (3239)
(c) Ti-6Al-4V (3481)

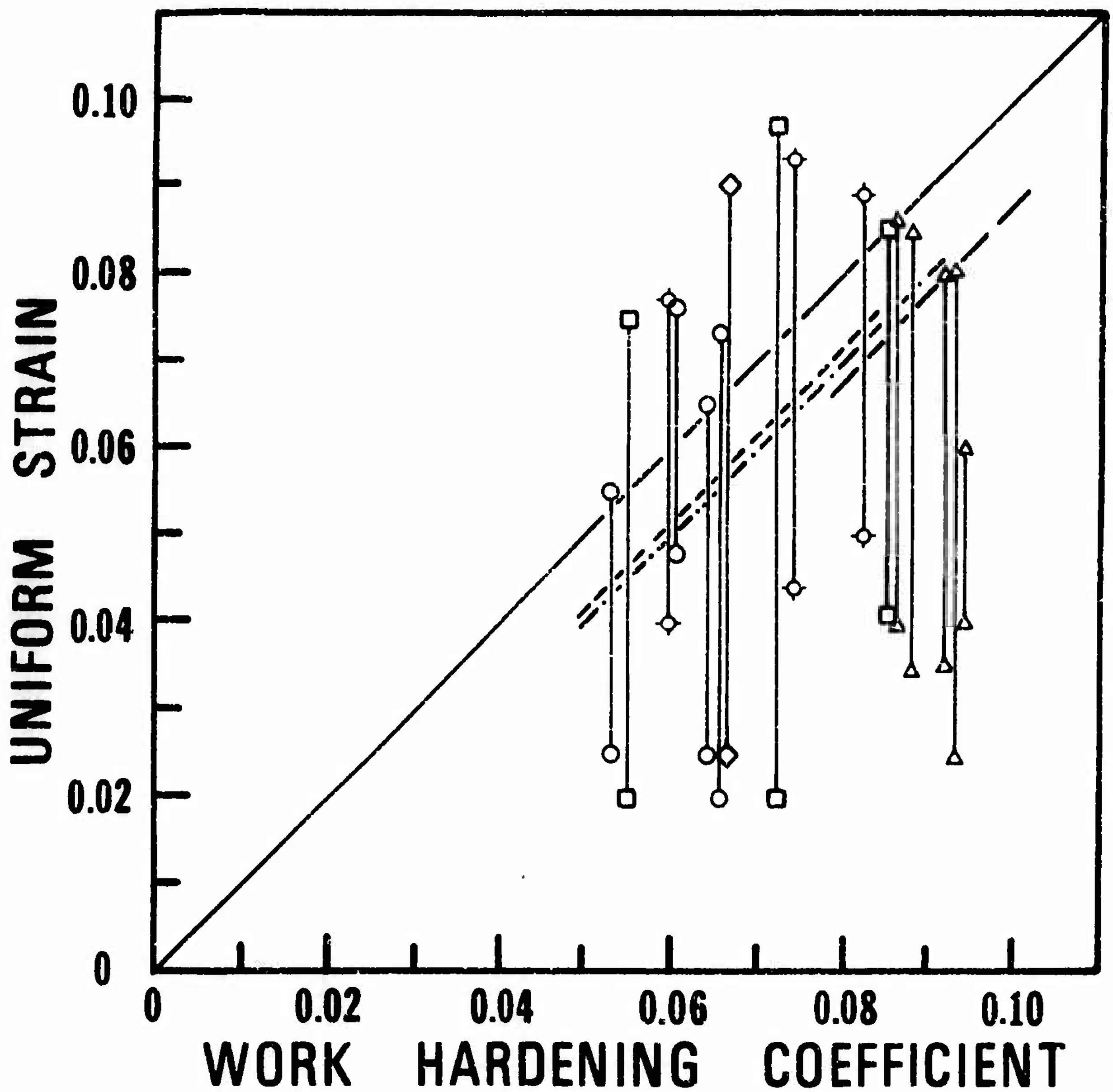

Figure 6. Uniform strain plotted against work hardening coefficient. Note that, while the full line refers to total strain, all the data points and the dashed lines refer to true plastic strain. (a) Uniform strain data derived directly from the chart record.

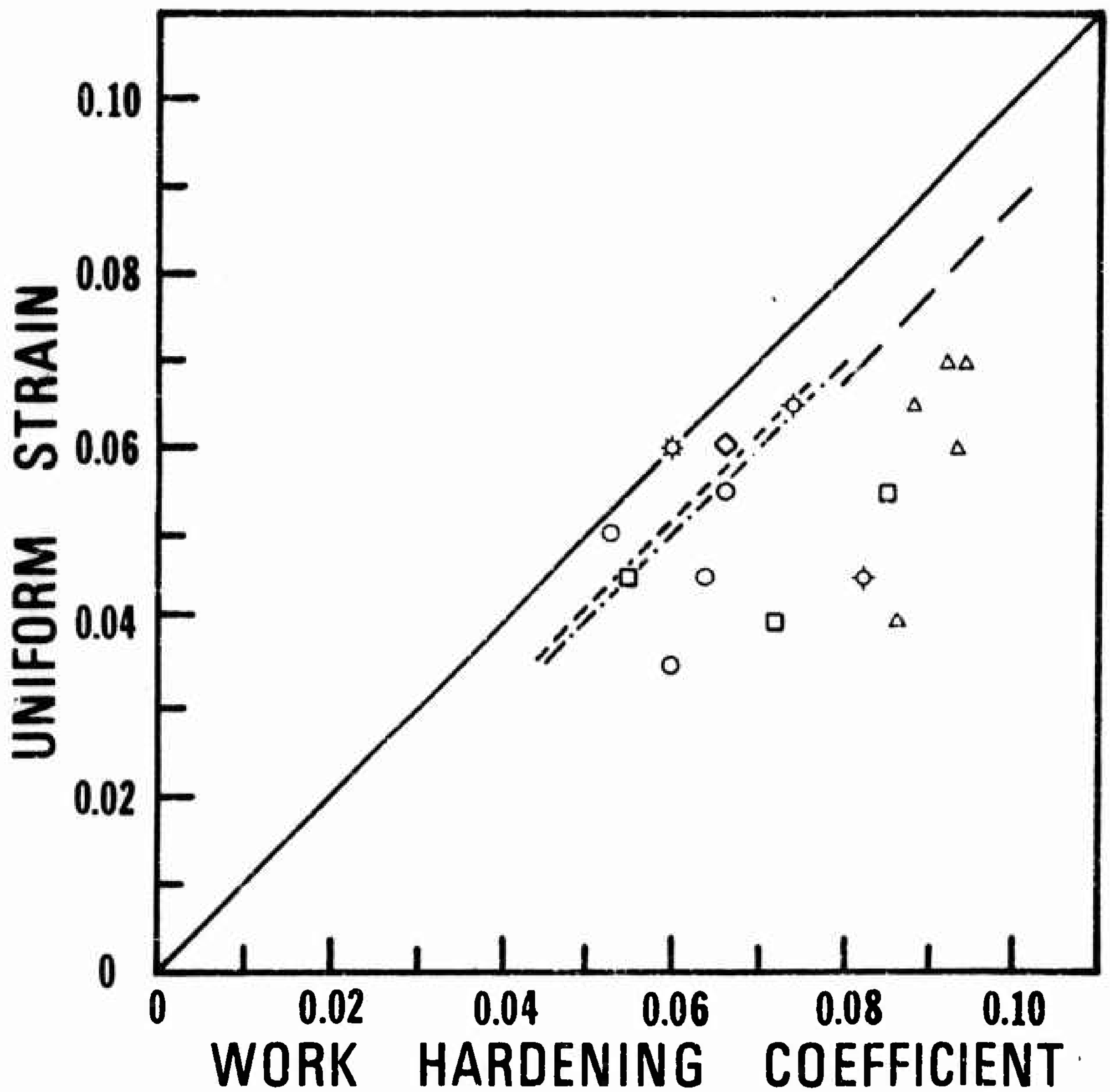

Figure 6. Uniform strain plotted against work hardening coefficient. Note that, while the full line refers to total strain, all the data points and the dashed lines refer to true plastic strain. (b) Uniform strain derived by means of Considère's construction.

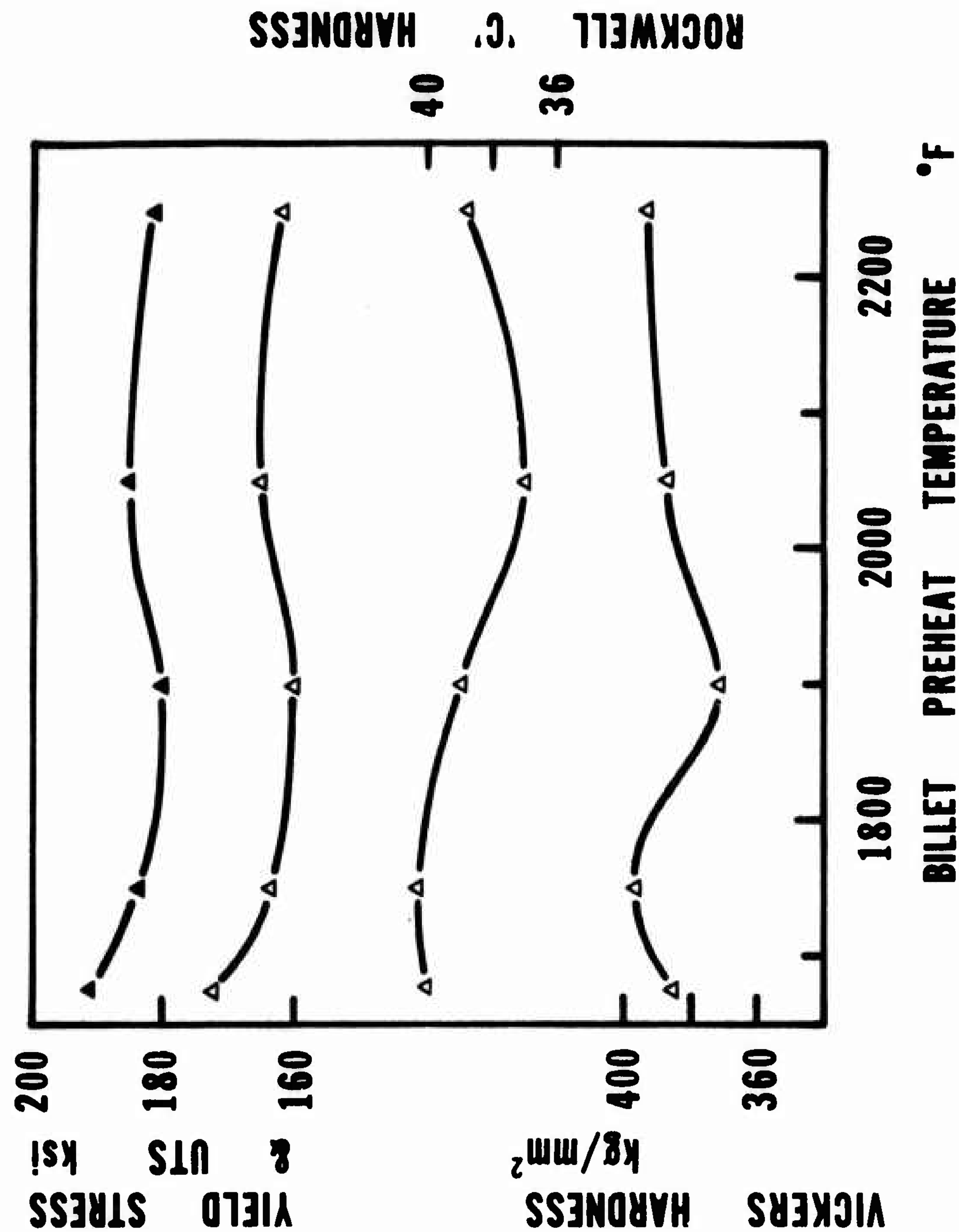

Figure 7. Yield and ultimate tensile stresses and Rockwell "C" hardness as a function of billet preheat temperature, after Gurney and Male[6]. Vickers hardness, determined in the present study, is also incorporated.
(a) Ti-13V-11Cr-3Al

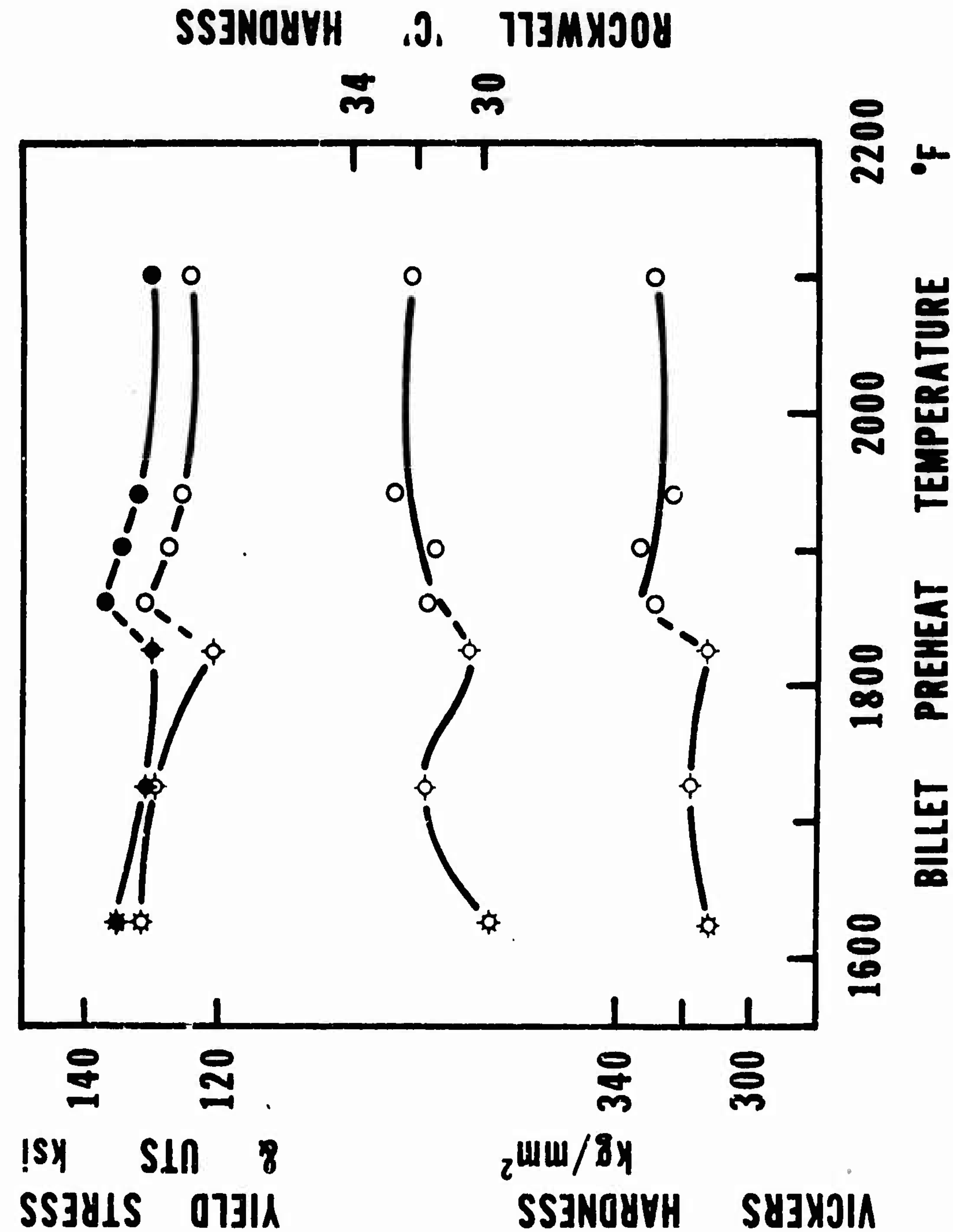

Figure 7. Yield and ultimate tensile stresses and Rockwell "C" hardness as a function of billet preheat temperature, after Gurney and Male[6]. Vickers hardness, determined in the present study, is also incorporated.
(b) Ti-5Al-2.5Sn

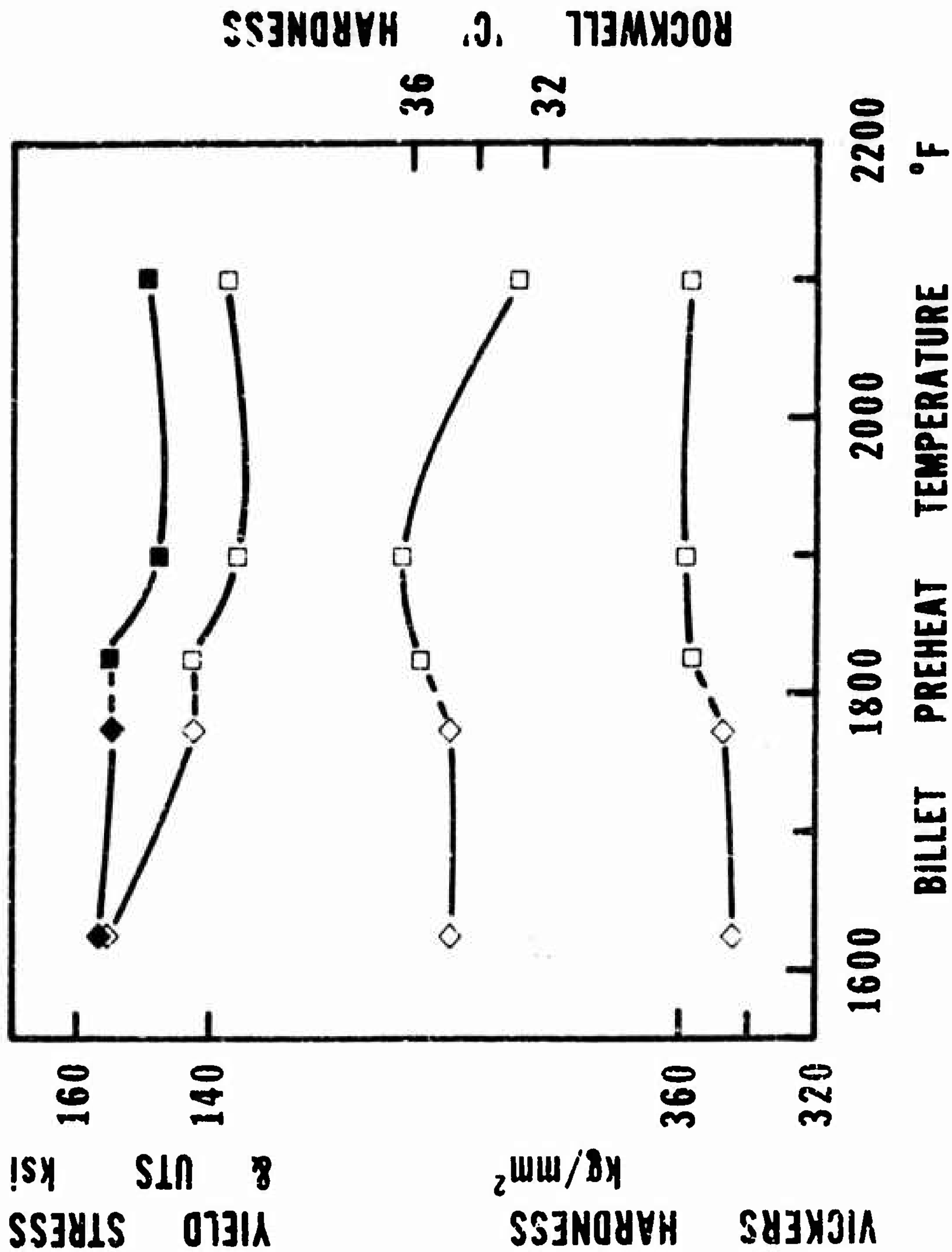

Figure 7. Yield and ultimate tensile stresses and Rockwell "C" hardness as a function of billet preheat temperature, after Gurney and Male[6]. Vickers hardness, determined in the present study, is also incorporated.
(c) Ti-6Al-4V

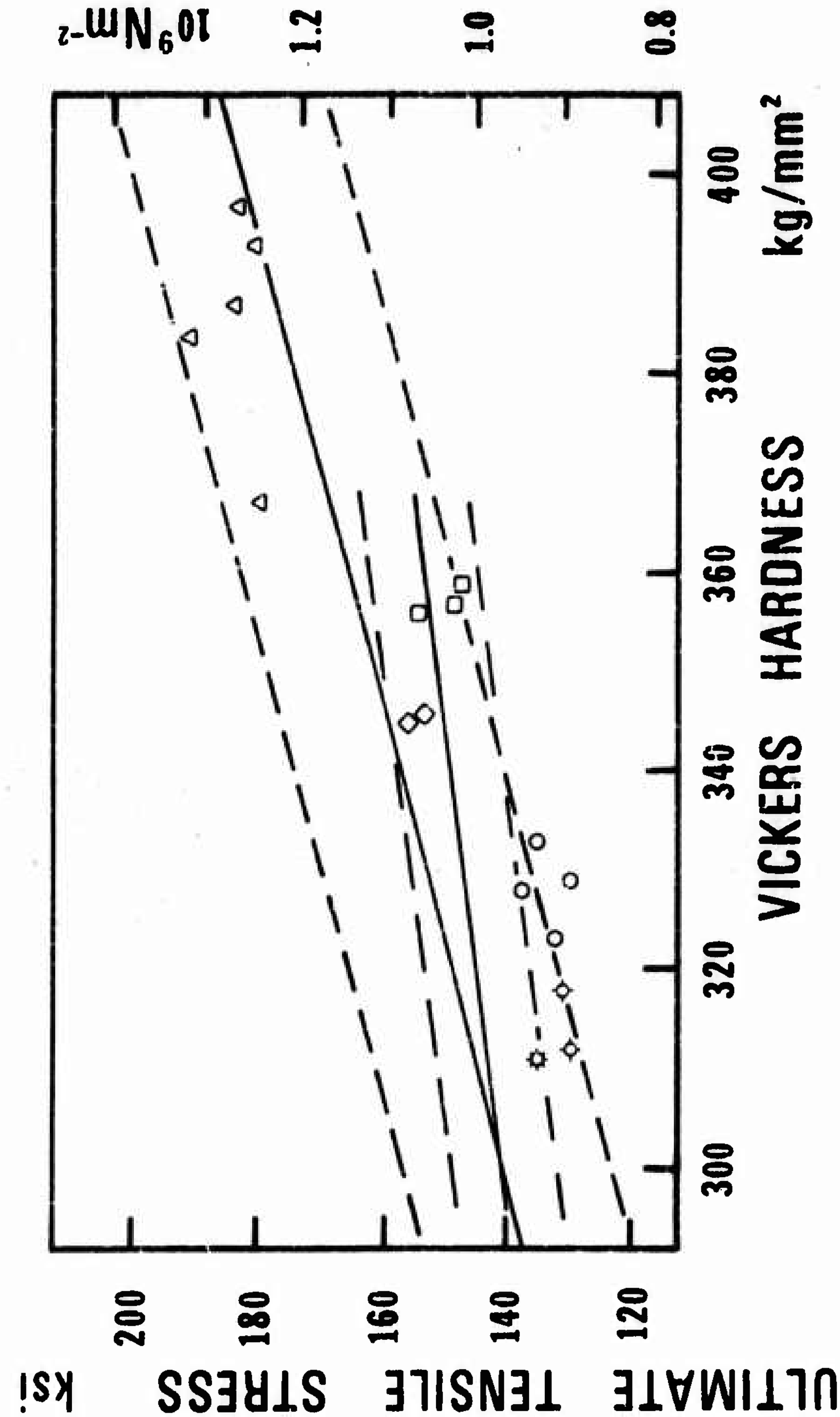

Figure 8. Comparison of ultimate tensile stress/hardness correlations from the present work with those of Hickey[9]. The lines represent the relationship(s), and ± two standard deviations, given by Hickey.
(a) UTS vs. Vickers hardness.

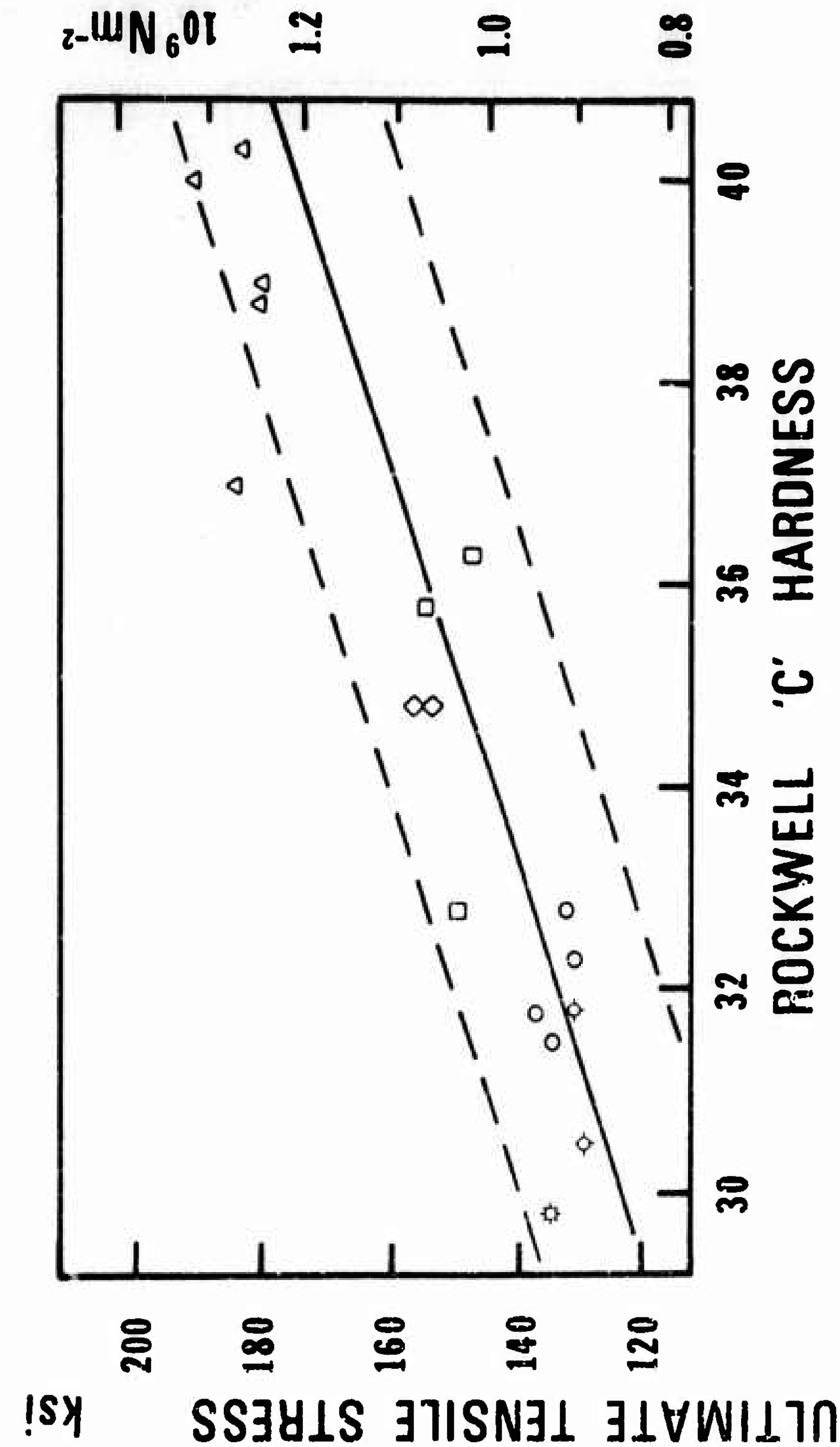

Figure 8. Comparison of ultimate tensile stress/hardness correlations from the present work with those of Hickey[9]. The lines represent the relationship(s), and ± two standard deviations, given by Hickey.
(b) UTS vs. Rockwell "C" hardness.

VII APPENDICES

7.1. Relation Between Uniform Elongation and n (See Ref. 5)

For those materials which obey Eq. 2 relating true stress and true strain

$$(\sigma = K\varepsilon^{n})$$

$$\frac{d\sigma}{d\varepsilon} = nK\varepsilon^{n-1} = \frac{n}{\varepsilon}\sigma \qquad (A1.1)$$

by differentiation. Also, by definition,

$$\varepsilon = \ln(1+e) \qquad (A1.2)$$

where e = engineering strain. Therefore

$$d\varepsilon = \frac{de}{(1+e)} \qquad (A1.3)$$

By combining Eqs. A1.1 and A1.3

$$\frac{d\sigma}{de} = \frac{n}{\varepsilon}\frac{\sigma}{(1+e)} \qquad (A1.4)$$

Comparison of Eq. A1.4 with Eq. A2.4 of appendix 2, appropriate to peak load, gives

$$\frac{n}{\varepsilon_u} = 1$$

or (A1.5)

$$\varepsilon_u = n$$

where ε_u is the total (i.e. elastic plus plastic) true strain at peak load.

7.2. Considère's Construction (See Ref. 5)

True stress σ, load L, initial area A_o and engineering strain e are related by the equation

$$\sigma = \frac{L}{A_o} (1 + e) \qquad (A2.1)$$

Partial differentiation of this equation yields

$$\frac{\partial\sigma}{\partial e} = \frac{(1+e)}{A_o} \frac{\partial L}{\partial e} + \frac{L}{A_o} \qquad (A2.2)$$

At peak load, $\partial L/\partial e$ is zero so the Eq. A2.2 becomes

$$\frac{d\sigma}{de}\text{ peak load} = \frac{L_u}{A_o} \qquad (A2.3)$$

where the suffix u indicates peak load. By the incorporation of Eq. A2.1,

$$\frac{d\sigma}{de}\text{ peak load} = \frac{\sigma_u}{1 + e_u} \qquad (A2.4)$$

The implication of Eq. A2.4 is that a tangent to a curve of true stress vs. engineering strain, drawn from a point of strain -1, touches the curve at a point corresponding to peak load. This device is known as Considère's construction.

7.3. Computer Program and Output for Brinell Test Data

```
C     ******************************************************************
C     *                                                                *
C     *                     BRINELL HARDNESS                           *
C     *                                                                *
C     * THIS PROGRAM COMPUTES BRINELL AND MEYER HARDNESS VALUES        *
C     * AND RATIOS OF HARDNESS TO FLOW STRESS.  IT USES A SERIES       *
C     * OF INDENTATION DIAMETERS AND FLOW STRESS VALUES AND GEN-       *
C     * ERATES DATA FOR INDENTER LOADS OF 5,10,20 AND 40 KG.           *
C     *                                                                *
C     ******************************************************************
      DIMENSION ANO(1),W(4)
      DATA W/5.,10.,20.,40./
      FACTOR=1.42/2.8
      PI=3.1416
      J=0
      READ(5,1) L
C     READS NUMBER OF DATA SETS
      READ(5,2) D
C     READS DIAMETER OF INDENTING BALL
      DSQRD=D**2
      DO 10 N=1,L
      READ(5,3) ANO
C     READS EXTRUSION NUMBER
      J=J+1
      IF(J.EQ.2) GO TO 20
      WRITE(6,4) ANO
      GO TO 21
   20 WRITE(6,5) ANO
      J=J-2
   21 WRITE(6,6) D
      WRITE(6,7)
      WRITE(6,8)
      WRITE(6,9)
      TOTALB=0.0
      TOTALM=0.0
      I=0
      DO 10 M=1,4
      READ(5,11) DELTA,SIGMAP
C     READS INDENTATION DIAMETER AND FLOW STRESS AT EQUIVALENT
C     PLASTIC STRAIN
      SQR=DELTA**2
      BRINELL=2.0*W(M)/(PI*D*(D-SQRT(DSQRD-SQR)))
C     COMPUTES BRINELL HARDNESS VALUE
      AMEYER=4.0*W(M)/(PI*SQR)
C     COMPUTES MEYER HARDNESS VALUE
      SIGESTB=BRINELL*FACTOR
      SIGESTM=AMEYER*FACTOR
C     COMPUTE HARDNESS/2.8 VALUES AND CONVERT TO KSI
```

```
      IF(SIGMAP.EQ.0) GO TO 25
      RATIOB=BRINELL/SIGMAP
      RATIOM=AMEYER/SIGMAP
C     CALCULATE RATIOS OF HARDNESS TO FLOW STRESS
      RATIOXB=1.42*RATIOB
      RATIOXM=1.42*RATIOM
      TOTALB=TOTALB+RATIOB
      TOTALM=TOTALM+RATIOM
C     DETERMINE RUNNING TOTALS OF VALUES OF 'RATIOB' AND 'RATIOM'
      WRITE(6,12) W(M),DELTA,SIGMAP,BRINELL,RATIOB,RATIOXB,
     +AMEYER,RATIOM,RATIOXM,SIGESTB,SIGESTM
      IF(M-4) 10,30,30
   25 WRITE(6,13) W(M),DELTA,BRINELL,AMEYER,SIGESTB,SIGESTM
      I=I+1
      IF(M.LT.4) GO TO 10
      RMEANM=TOTALM/(M-I)
      RMEANB=TOTALB/(M-I)
      GO TO 35
   30 RMEANB=TOTALB/M
      RMEANM=TOTALM/M
C     DETERMINE MEAN VALUES OF 'RATIOB' AND RATIOM'
   35 XBMEAN=1.42*RMEANB
      XMMEAN=1.42*RMEANM
      WRITE(6,14) RMEANB,XBMEAN,RMEANM,XMMEAN
   10 CONTINUE
    1 FORMAT (I2)
    2 FORMAT (1X,F3.1)
    3 FORMAT (A10)
    4 FORMAT (1H1////,T12,*EXTRUSION NUMBER*,A10)
    5 FORMAT (////,T12,*EXTRUSION NUMBER*,A10)
    6 FORMAT (T12,*(BRINELL AND MEYER HARDNESS DATA, *,-3.1,
     +9H MM BALL)/)
    7 FORMAT (T12,*LOAD*,T17,*INDENT.*,T25,*FLOW*,T31,*BRINELL*,
     +T40,*HB/SIG.*,T48,*HB/SIG.*,T58,*MEYER*,T65,*HM/SIG.*,T73,
     +*HM/SIG.*,T82,*HB/2.8*,T90,*HM/2.8*)
    8 FORMAT (T18,*DIAM.*,T24,*STRESS*,T31,*HARDNESS*,T41,*MIXED*,
     +T48,*DIMEN-*,T57,*HARDNESS*,T66,*MIXED*,T73,*DIMEN-*)
    9 FORMAT (T13,*KG*,T19,*MM*,T27,*KSI*,T41,*UNITS*,T48,*SIONLESS*,
     +T66,*UNITS*,T73,*SIONLESS*,T83,*KSI*,T91,*KSI*/)
   11 FORMAT (1X,F5.3,1X,F5.1)
   12 FORMAT (11X,F4.0,1X,F5.3,2X,F5.1,3X,F5.1,4X,2(F5.3,3X),1X,
     +F5.1,3X,2(F5.3,3X),1X,2(F5.1,3X))
   13 FORMAT (11X,F4.0,1X,F5.3,2X,5H   -   ,3X,F5.1,4X,2(5H   -   ,3X),
     +1X,F5.1,3X,2(5H   -   ,3X),1X,2(F5.1,3X))
   14 FORMAT (/T12,*MEAN VALUES*,18X,2(F5.3,3X,)9X,2(F5.3,3X))
      STOP
      END
```

EXTRUSION NUMBER 3375
(BRINELL AND MEYER HARDNESS DATA, 1.0 MM BALL)

LOAD KG	INDENT. DIAM. MM	FLOW STRESS KSI	BRINELL HARDNESS	HB/SIG. MIXED UNITS	HB/SIG. DIMEN-SIONLESS	MEYER HARDNESS	HM/SIG. MIXED UNITS	HM/SIG. DIMEN-SIONLESS	HB/2.8 KSI	HM/2.8 KSI
5.	.148	190.9	289.0	1.514	2.150	290.6	1.522	2.162	146.6	147.4
10.	.201	195.7	311.9	1.594	2.263	315.1	1.610	2.287	158.2	159.8
20.	.266	200.6	353.4	1.762	2.502	359.9	1.794	2.548	179.2	182.5
40.	.372	203.5	354.8	1.744	2.476	368.0	1.809	2.568	179.9	186.5
MEAN VALUES				1.653	2.348		1.684	2.391		

EXTRUSION NUMBER 3303
(BRINELL AND MEYER HARDNESS DATA, 1.0 MM BALL)

LOAD KG	INDENT. DIAM. MM	FLOW STRESS KSI	BRINELL HARDNESS	HB/SIG. MIXED UNITS	HB/SIG. DIMEN-SIONLESS	MEYER HARDNESS	HM/SIG. MIXED UNITS	HM/SIG. DIMEN-SIONLESS	HB/2.8 KSI	HM/2.8 KSI
5.	.146	185.2	297.1	1.604	2.278	298.7	1.613	2.290	150.7	151.5
10.	.192	188.5	342.2	1.815	2.578	345.4	1.832	2.602	173.5	175.2
20.	.269	192.9	345.4	1.791	2.543	351.9	1.824	2.591	175.2	178.5
40.	.363	196.3	373.3	1.902	2.701	386.5	1.969	2.796	189.3	195.0
MEAN VALUES				1.778	2.525		1.810	2.570		

EXTRUSION NUMBER 3272
(BRINELL AND MEYER HARDNESS DATA, 1.0 MM BALL)

LOAD KG	INDENT. DIAM. MM	FLOW STRESS KSI	BRINELL HARDNESS	HB/SIG. MIXED UNITS	HB/SIG. DIMEN-SIONLESS	MEYER HARDNESS	HM/SIG. MIXED UNITS	HM/SIG. DIMEN-SIONLESS	HB/2.8 KSI	HM/2.8 KSI
5.	.155	184.6	263.4	1.427	2.026	265.0	1.435	2.038	133.6	134.4
10.	.202	187.1	308.8	1.651	2.344	312.0	1.668	2.368	156.6	158.2
20.	.267	189.5	350.7	1.851	2.628	357.2	1.885	2.677	177.9	181.2
40.	.363	-	373.3	-	-	386.5	-	-	189.3	195.0
MEAN VALUES				1.643	2.333		1.663	2.361		

EXTRUSION NUMBER 3385
(BRINELL AND MEYER HARDNESS DATA, 1.0 MM BALL)

LOAD KG	INDENT. DIAM. MM	FLOW STRESS KSI	BRINELL HARDNESS	HB/SIG. MIXED UNITS	HB/SIG. DIMEN-SIONLESS	MEYER HARDNESS	HM/SIG. MIXED UNITS	HM/SIG. DIMEN-SIONLESS	HB/2.8 KSI	HM/2.8 KSI
5.	.155	186.1	263.4	1.415	2.010	265.0	1.424	2.022	133.6	134.4
10.	.202	190.0	308.8	1.625	2.308	312.0	1.642	2.332	156.6	158.2
20.	.265	193.7	356.1	1.839	2.611	362.6	1.872	2.658	180.6	183.9
40.	.368	197.6	362.9	1.836	2.608	376.1	1.903	2.703	184.0	190.7
MEAN VALUES				1.679	2.384		1.710	2.429		

EXTRUSION NUMBER 3331
(BRINELL AND MEYER HARDNESS DATA, 1.0 MM BALL)

LOAD KG	INDENT. DIAM. MM	FLOW STRESS KSI	BRINELL HARDNESS	HB/SIG. MIXED UNITS	HB/SIG. DIMEN-SIONLESS	MEYER HARDNESS	HM/SIG. MIXED UNITS	HM/SIG. DIMEN-SIONLESS	HB/2.8 KSI	HM/2.8 KSI
5.	.146	181.1	297.1	1.640	2.329	298.7	1.649	2.342	150.7	151.5
10.	.204	185.4	302.7	1.633	2.319	305.9	1.650	2.343	153.5	155.2
20.	.267	190.4	350.7	1.842	2.616	357.2	1.876	2.664	177.9	181.2
40.	.360	194.2	379.8	1.956	2.777	393.0	2.024	2.873	192.6	199.3
MEAN VALUES				1.768	2.510		1.800	2.556		

EXTRUSION NUMBER 3246
(BRINELL AND MEYER HARDNESS DATA, 1.0 MM BALL)

LOAD KG	INDENT. DIAM. MM	FLOW STRESS KSI	BRINELL HARDNESS	HB/SIG. MIXED UNITS	HB/SIG. DIMEN-SIONLESS	MEYER HARDNESS	HM/SIG. MIXED UNITS	HM/SIG. DIMEN-SIONLESS	HB/2.8 KSI	HM/2.8 KSI
5.	.245	141.2	104.4	.740	1.050	106.1	.751	1.067	53.0	53.8
10.	.307	142.8	131.8	.923	1.311	135.1	.946	1.343	66.9	68.5
20.	.385	144.3	165.2	1.145	1.625	171.8	1.191	1.691	83.8	87.1
40.	.493	-	195.9	-	-	209.5	-	-	99.4	106.3
MEAN VALUES				.936	1.329		.963	1.367		

EXTRUSION NUMBER 3174
(BRINELL AND MEYER HARDNESS DATA, 1.0 MM BALL)

LOAD KG	INDENT. DIAM. MM	FLOW STRESS KSI	BRINELL HARDNESS	HB/SIG. MIXED UNITS	HB/SIG. DIMEN-SIONLESS	MEYER HARDNESS	HM/SIG. MIXED UNITS	HM/SIG. DIMEN-SIONLESS	HB/2.8 KSI	HM/2.8 KSI
5.	.253	137.6	97.8	.711	1.010	99.5	.723	1.026	49.6	50.4
10.	.307	139.1	131.8	.948	1.346	135.1	.971	1.379	66.9	68.5
20.	.384	141.2	166.1	1.176	1.670	172.7	1.223	1.737	84.2	87.6
40.	.490	-	198.5	-	-	212.1	-	-	100.7	107.6
MEAN VALUES				.945	1.342		.972	1.381		

EXTRUSION NUMBER 3239
(BRINELL AND MEYER HARDNESS DATA, 1.0 MM BALL)

LOAD KG	INDENT. DIAM. MM	FLOW STRESS KSI	BRINELL HARDNESS	HB/SIG. MIXED UNITS	HB/SIG. DIMEN-SIONLESS	MEYER HARDNESS	HM/SIG. MIXED UNITS	HM/SIG. DIMEN-SIONLESS	HB/2.8 KSI	HM/2.8 KSI
5.	.247	136.2	102.7	.754	1.071	104.3	.766	1.088	52.1	52.9
10.	.311	138.4	128.4	.928	1.317	131.6	.951	1.351	65.1	66.8
20.	.389	140.1	161.7	1.154	1.638	168.3	1.201	1.706	82.0	85.3
40.	.490	-	198.5	-	-	212.1	-	-	100.7	107.6
MEAN VALUES				.945	1.342		.973	1.381		

EXTRUSION NUMBER 3241
(BRINELL AND MEYER HARDNESS DATA, 1.0 MM BALL)

LOAD KG	INDENT. DIAM. MM	FLOW STRESS KSI	BRINELL HARDNESS	HB/SIG. MIXED UNITS	HB/SIG. DIMEN-SIONLESS	MEYER HARDNESS	HM/SIG. MIXED UNITS	HM/SIG. DIMEN-SIONLESS	HB/2.8 KSI	HM/2.8 KSI
5.	.243	143.8	106.2	.738	1.049	107.8	.750	1.065	53.9	54.7
10.	.307	144.7	131.8	.911	1.294	135.1	.934	1.326	66.9	68.5
20.	.380	-	169.7	-	-	176.3	-	-	86.1	89.4
40.	.490	-	198.5	-	-	212.1	-	-	100.7	107.6
MEAN VALUES				.825	1.171		.842	1.195		

EXTRUSION NUMBER 3167
(BRINELL AND MEYER HARDNESS DATA, 1.0 MM BALL)

LOAD KG	INDENT. DIAM. MM	FLOW STRESS KSI	BRINELL HARDNESS	HB/SIG. MIXED UNITS	HB/SIG. DIMEN-SIONLESS	MEYER HARDNESS	HM/SIG. MIXED UNITS	HM/SIG. DIMEN-SIONLESS	HB/2.8 KSI	HM/2.8 KSI
5.	.244	141.6	105.3	.744	1.056	106.9	.755	1.072	53.4	54.2
10.	.305	142.2	133.6	.940	1.334	136.9	.963	1.367	67.8	69.4
20.	.374	-	175.4	-	-	182.1	-	-	89.0	92.3
40.	.474	-	213.1	-	-	226.7	-	-	108.1	115.0
MEAN VALUES				.842	1.195		.859	1.220		

EXTRUSION NUMBER 3243
(BRINELL AND MEYER HARDNESS DATA, 1.0 MM BALL)

LOAD KG	INDENT. DIAM. MM	FLOW STRESS KSI	BRINELL HARDNESS	HB/SIG. MIXED UNITS	HB/SIG. DIMEN-SIONLESS	MEYER HARDNESS	HM/SIG. MIXED UNITS	HM/SIG. DIMEN-SIONLESS	HB/2.8 KSI	HM/2.8 KSI
5.	.247	143.3	102.7	.717	1.018	104.3	.728	1.034	52.1	52.9
10.	.298	144.4	140.1	.970	1.378	143.4	.993	1.410	71.1	72.7
20.	.380	-	169.7	-	-	176.3	-	-	86.1	89.4
40.	.476	-	211.2	-	-	224.8	-	-	107.1	114.0
MEAN VALUES				.844	1.198		.861	1.222		

EXTRUSION NUMBER 3234
(BRINELL AND MEYER HARDNESS DATA, 1.0 MM BALL)

LOAD KG	INDENT. DIAM. MM	FLOW STRESS KSI	BRINELL HARDNESS	HB/SIG. MIXED UNITS	HB/SIG. DIMEN-SIONLESS	MEYER HARDNESS	HM/SIG. MIXED UNITS	HM/SIG. DIMEN-SIONLESS	HB/2.8 KSI	HM/2.8 KSI
5.	.245	137.8	104.4	.758	1.076	106.1	.770	1.093	53.0	53.8
10.	.302	138.4	136.3	.985	1.399	139.6	1.009	1.432	69.1	70.8
20.	.388	-	162.5	-	-	169.2	-	-	82.4	85.8
40.	.493	-	195.9	-	-	203.5	-	-	99.4	106.3
MEAN VALUES				.872	1.238		.889	1.263		

EXTRUSION NUMBER 3475
(BRINELL AND MEYER HARDNESS DATA, 1.0 MM BALL)

LOAD KG	INDENT. DIAM. MM	FLOW STRESS KSI	BRINELL HARDNESS	HB/SIG. MIXED UNITS	HB/SIG. DIMEN-SIONLESS	MEYER HARDNESS	HM/SIG. MIXED UNITS	HM/SIG. DIMEN-SIONLESS	HB/2.8 KSI	HM/2.8 KSI
5.	.251	160.3	99.4	.620	.881	101.0	.630	.895	50.4	51.2
10.	.302	162.1	136.3	.841	1.194	139.6	.861	1.223	69.1	70.8
20.	.379	164.4	170.7	1.038	1.474	177.3	1.078	1.531	86.6	89.9
40.	.474	166.4	213.1	1.281	1.819	226.7	1.362	1.934	108.1	115.0
MEAN VALUES				.945	1.342		.983	1.396		

EXTRUSION NUMBER 3481
(BRINELL AND MEYER HARDNESS DATA, 1.0 MM BALL)

LOAD KG	INDENT. DIAM. MM	FLOW STRESS KSI	BRINELL HARDNESS	HB/SIG. MIXED UNITS	HB/SIG. DIMEN-SIONLESS	MEYER HARDNESS	HM/SIG. MIXED UNITS	HM/SIG. DIMEN-SIONLESS	HB/2.8 KSI	HM/2.8 KSI
5.	.244	163.0	105.3	.646	.917	106.9	.656	.932	53.4	54.2
10.	.291	164.5	147.1	.894	1.270	150.4	.914	1.298	74.6	76.3
20.	.369	167.0	180.4	1.080	1.534	187.0	1.120	1.590	91.5	94.8
40.	.467	168.0	220.0	1.310	1.860	233.5	1.390	1.974	111.6	118.4
MEAN VALUES				.983	1.395		1.020	1.448		

EXTRUSION NUMBER 3169
(BRINELL AND MEYER HARDNESS DATA, 1.0 MM BALL)

LOAD KG	INDENT. DIAM. MM	FLOW STRESS KSI	BRINELL HARDNESS	HB/SIG. MIXED UNITS	HB/SIG. DIMEN-SIONLESS	MEYER HARDNESS	HM/SIG. MIXED UNITS	HM/SIG. DIMEN-SIONLESS	HB/2.8 KSI	HM/2.8 KSI
5.	.243	141.0	106.2	.753	1.069	107.8	.765	1.086	53.9	54.7
10.	.313	142.6	126.7	.888	1.262	130.0	.911	1.294	64.3	65.9
20.	.381	-	168.8	-	-	175.4	-	-	85.6	89.0
40.	.472	-	215.1	-	-	228.6	-	-	109.1	115.9
MEAN VALUES				.821	1.166		.838	1.190		

EXTRUSION NUMBER 3235
(BRINELL AND MEYER HARDNESS DATA, 1.0 MM BALL)

LOAD KG	INDENT. DIAM. MM	FLOW STRESS KSI	BRINELL HARDNESS	HB/SIG. MIXED UNITS	HB/SIG. DIMEN-SIONLESS	MEYER HARDNESS	HM/SIG. MIXED UNITS	HM/SIG. DIMEN-SIONLESS	HB/2.8 KSI	HM/2.8 KSI
5.	.240	154.0	108.9	.707	1.004	110.5	.718	1.019	55.2	56.1
10.	.297	156.1	141.1	.904	1.283	144.3	.925	1.313	71.6	73.2
20.	.370	158.5	179.4	1.132	1.607	186.0	1.174	1.666	91.0	94.3
40.	.472	161.9	215.1	1.328	1.886	228.6	1.412	2.005	109.1	115.9
MEAN VALUES				1.018	1.445		1.057	1.501		

```
C     ****************************************************************
C     *                                                              *
C     *                STRESS-STRAIN 3 (PLASTIC STRAIN)              *
C     *                                                              *
C     *  THIS PROGRAM CALCULATES ENGINEERING STRAIN, TRUE STRAIN,    *
C     *  TRUE STRESS, LOG10(TRUE STRAIN), AND LOG10(TRUE STRESS)     *
C     *  FROM CHART ELONGATION (IN INCHES) AND FROM LOAD VALUES      *
C     *                                                              *
C     ****************************************************************
      DIMENSION ANO(3)
      CHTFACT=2.86
C     THIS FACTOR IS USED TO CONVERT CHART DISPLACEMENT, IN INCHES,
C     TO % ENGINEERING STRAIN FOR A UNIFORM SECTION LENGTH OF
C     1.75 INCHES
      READ(5,11)I
C     READS NUMBER OF DATA SETS
      DO 20 M=1,I
      READ(5,8)ANO
C     READS EXTRUSION NUMBER
      READ(5,1)L
C     READS NUMBER OF CHART POINTS
      READ(5,3) ALO,DELLO
C     READS COORDINATES OF A POINT ON THE ELASTIC PART OF THE CHART
      READ(5,2) D
C     READS SPECIMEN DIAMETER
      WRITE(6,9)ANO
      WRITE(6,12)
      WRITE(6,5)
      WRITE(6,6)
      WRITE(6,7)
      A=3.1416*D**2/4.
      RATIO=DELLO/ALO
      DO 20 N=1,L
      READ(5,3)AL,DELTAL
C     READS COORDINATES OF A POINT ON THE CHART (LOAD IN LBS AND
C     DISPLACEMENT IN INCHES OF CHART)
      ENG=(DELTAL-AL*RATIO)*CHTFACT
C     CALCULATES ENGINEERING STRAIN FROM TOTAL CHART INCHES BY FIRST
C     SUBTRACTING AN EXTRAPOLATION OF THE INITIAL LOADING CURVE
      STRN=0.01*ENG
      TERMA=1.+STRN
      EPSILON=ALOG(TERMA)
      SIGMA=0.001*AL*TERMA/A
      TERMB=ALOG10(EPSILON)
      TERMC=ALOG10(SIGMA)
      WRITE(6,4)AL,DELTAL,ENG,TERMA,SIGMA,EPSILON,TERMC,TERMB
   20 CONTINUE
    1 FORMAT(I3)
```

```
 2 FORMAT(1X,F5.3)
 3 FORMAT(1X,F5.0,1X,F4.2)
 4 FORMAT(11X,F6.0,1X,F4.2,1X,F6.2,1X,F6.3,1X,F6.1,1X,F6.3,2X,
  +F6.3,2X,F6.3)
 5 FORMAT(T12,*LOAD*,T18,*CHART*,T26,*ENG.*,T33,*1+E*,T39,*TRUE*,
  +T46,*TRUE*,T53,*LOG10*,T61,*LOG10*)
 6 FORMAT(T18,*ELONG.*,T25,*STRAIN*,T38,*STRESS*,T45,*STRAIN*,
  +T53,*STRESS*,T61,*STRAIN*)
 7 FORMAT(T12,*LBS.*,T19,*INS.*,T27,*%*,T39,*KSI*/)
 8 FORMAT(A10,A10,A10)
 9 FORMAT(1H1,//////T12,*EXTRUSION NUMBER*,3A10)
11 FORMAT(I2)
12 FORMAT(T12,*( PLASTIC STRAIN )*/)
   CONTINUE
   STOP
   END
```

```
C     ****************************************************************
C     *                                                              *
C     *          STRESS-STRAIN 2 (CORRECTED TOTAL STRAIN)            *
C     *                                                              *
C     *  THIS PROGRAM CALCULATES ENGINEERING STRAIN, TRUE STRAIN,    *
C     *  TRUE STRESS, LOG10(TRUE STRAIN), AND LOG10(TRUE STRESS)     *
C     *  FROM CHART ELONGATION (IN INCHES) AND FROM LOAD VALUES      *
C     *                                                              *
C     ****************************************************************
      DIMENSION ANO(3)
      CHTFACT=2.86
C     THIS FACTOR IS USED TO CONVERT CHART DISPLACEMENT, IN INCHES,
C     TO % ENGINEERING STRAIN FOR A UNIFORM SECTION LENGTH OF
C     1.75 INCHES
      READ(5,11)I
C     READS NUMBER OF DATA SETS
      DO 20 M=1,I
      READ(5,8)ANO
C     READS EXTRUSION NUMBER
      READ(5,1)L
C     READS NUMBER OF CHART POINTS
      READ(5,3) ALO,DELLO
C     READS COORDINATES OF A POINT ON THE ELASTIC PART OF THE CHART
      READ(5,2) D
C     READS SPECIMEN DIAMETER
      WRITE(6,9)ANO
      WRITE(6,12)
      WRITE(6,5)
      WRITE(6,6)
      WRITE(6,7)
      RATIO=DELLO/ALO
      A=3.1416*D**2/4.
      E=16.5 E6
      AEINV=1./(A*E)
      DO 20 N=1,L
      READ(5,3)AL,DELTAL
C     READS COORDINATES OF A POINT ON THE CHART (LOAD IN LBS AND
C     DISPLACEMENT IN INCHES OF CHART)
      ENG=(DELTAL-AL*RATIO)*CHTFACT+AL*AEINV*100.
C     CALCULATES ENGINEERING STRAIN FROM TOTAL CHART INCHES BY FIRST
C     SUBTRACTING AN EXTRAPOLATION OF THE INITIAL LOADING CURVE.
C     ELASTIC STRAIN IS ESTIMATED FOR E = 16,500 KSI AND IS ADDED TO
C     THE PLASTIC STRAIN DETERMINED FROM THE CHART.  THE STRAIN IS
C     THEN AN ESTIMATE OF 'TOTAL CORRECTED STRAIN'
      STRN=0.01*ENG
      TERMA=1.+STRN
      EPSILON=ALOG(TERMA)
      SIGMA=0.001*AL*TERMA/A
```

```
      TERMB=ALOG10(EPSILON)
      TERMC=ALOG10(SIGMA)
      WRITE(6,4)AL,DELTAL,ENG,TERMA,SIGMA,EPSILON,TERMC,TERMB
   20 CONTINUE
    1 FORMAT(I3)
    2 FORMAT(1X,F5.3)
    3 FORMAT(1X,F5.0,1X,F4.2)
    4 FORMAT(11X,F6.0,1X,F4.2,1X,F6.2,1X,F6.3,1X,F6.1,1X,F6.3,2X,
     +F6.3,2X,F6.3)
    5 FORMAT(T12,*LOAD*,T18,*CHART*,T26,*ENG.*,T33,*1+E*,T39,*TRUE*,
     +T46,*TRUE*,T53,*LOG10*,T61,*LOG10*)
    6 FORMAT(T18,*ELONG.*,T25,*STRAIN*,T38,*STRESS*,T45,*STRAIN*,
     +T53,*STRESS*,T61,*STRAIN*)
    7 FORMAT(T12,*LBS.*,T19,*INS.*,T27,*%*,T39,*KSI*/)
    8 FORMAT(A10,A10,A10)
    9 FORMAT(1H1,//////T12,*EXTRUSION NUMBER*,3A10)
   11 FORMAT(I2)
   12 FORMAT(T12,*( CORRECTED TOTAL STRAIN )*/)
      STOP
      END
```

EXTRUSION NUMBER 3375
(PLASTIC STRAIN)

LOAD LBS.	CHART ELONG. INS.	ENG. STRAIN %	1+E	TRUE STRESS KSI	TRUE STRAIN	LOG10 STRESS	LOG10 STRAIN
16800.	2.51	.12	1.001	174.8	.001	2.243	-2.938
17200.	2.71	.52	1.005	179.7	.005	2.255	-2.286
17400.	2.91	1.01	1.010	182.7	.010	2.262	-1.999
17500.	3.12	1.52	1.015	185.7	.015	2.269	-1.820
17750.	3.31	2.00	1.020	188.2	.020	2.275	-1.702
17800.	3.51	2.56	1.026	189.7	.025	2.278	-1.598
17300.	3.71	3.09	1.031	191.8	.030	2.283	-1.517
18000.	3.91	3.62	1.036	193.9	.036	2.287	-1.450
18100.	4.12	4.17	1.042	195.0	.041	2.292	-1.388
18200.	4.31	4.67	1.047	198.0	.046	2.297	-1.340
18300.	4.51	5.20	1.052	200.1	.051	2.301	-1.295
18300.	4.71	5.78	1.058	201.2	.056	2.304	-1.251
18300.	4.91	6.35	1.063	202.3	.062	2.306	-1.211
18300.	5.12	6.95	1.069	203.4	.067	2.308	-1.173
18200.	5.31	7.53	1.075	203.4	.073	2.308	-1.139
18100.	5.51	8.15	1.081	203.5	.078	2.308	-1.106
17750.	5.71	8.87	1.089	200.9	.085	2.303	-1.071
16500.	6.02	10.28	1.103	199.1	.098	2.277	-1.009

EXTRUSION NUMBER 3303
(PLASTIC STRAIN)

LOAD LBS.	CHART ELONG. INS.	ENG. STRAIN %	1+E	TRUE STRESS KSI	TRUE STRAIN	LOG10 STRESS	LOG10 STRAIN
16550.	2.81	.13	1.001	166.5	.001	2.221	-2.880
16900.	3.01	.54	1.005	170.7	.005	2.232	-2.271
17200.	3.20	.94	1.009	174.4	.009	2.242	-2.030
17450.	3.41	1.42	1.014	177.8	.014	2.250	-1.851
17652.	3.61	1.89	1.019	180.7	.019	2.257	-1.727
17775.	3.81	2.41	1.024	182.9	.024	2.262	-1.624
17900.	4.01	2.92	1.029	185.1	.029	2.267	-1.541
18000.	4.21	3.44	1.034	187.1	.034	2.272	-1.470
18100.	4.41	3.97	1.040	189.1	.039	2.277	-1.410
18150.	4.61	4.52	1.045	190.5	.044	2.280	-1.355
18175.	4.81	5.08	1.051	191.9	.050	2.283	-1.305
18200.	5.01	5.64	1.056	193.1	.055	2.286	-1.261
18250.	5.21	6.18	1.062	194.7	.060	2.289	-1.222
18250.	5.41	6.76	1.068	195.7	.065	2.292	-1.185
18200.	5.61	7.35	1.074	196.3	.071	2.293	-1.149
18100.	5.81	7.97	1.080	196.3	.077	2.293	-1.115
18000.	6.01	8.59	1.086	196.4	.082	2.293	-1.084
16500.	6.52	10.77	1.108	183.6	.102	2.264	-.990

EXTRUSION NUMBER 3272
(PLASTIC STRAIN)

LOAD LBS.	CHART ELONG. INS.	ENG. STRAIN %	1+E	TRUE STRESS KSI	TRUE STRAIN	LOG10 STRESS	LOG10 STRAIN
17500.	3.57	.40	1.004	173.5	.004	2.239	-2.398
17650.	3.77	.89	1.009	175.9	.009	2.245	-2.053
17780.	3.97	1.39	1.014	178.1	.014	2.251	-1.861
17900.	4.17	1.89	1.019	180.2	.019	2.256	-1.727
18000.	4.37	2.41	1.024	182.1	.024	2.260	-1.623
18100.	4.57	2.92	1.029	184.0	.029	2.265	-1.540
18150.	4.77	3.47	1.035	185.5	.034	2.268	-1.467
18180.	4.97	4.02	1.040	186.8	.039	2.271	-1.404
18200.	5.17	4.58	1.046	188.0	.045	2.274	-1.349
18200.	5.37	5.15	1.052	189.1	.050	2.277	-1.299
18180.	5.57	5.74	1.057	189.9	.056	2.279	-1.253
18150.	5.77	6.33	1.063	190.7	.061	2.280	-1.212
18100.	5.97	6.93	1.069	191.2	.067	2.281	-1.174
16500.	7.01	10.74	1.107	181.5	.102	2.259	-.991

EXTRUSION NUMBER 3385
(PLASTIC STRAIN)

LOAD LBS.	CHART ELONG. INS.	ENG. STRAIN %	1+E	TRUE STRESS KSI	TRUE STRAIN	LOG10 STRESS	LOG10 STRAIN
16550.	2.72	.16	1.002	166.5	.002	2.221	-2.800
16900.	2.92	.57	1.006	170.8	.006	2.232	-2.246
17150.	3.12	1.03	1.010	174.1	.010	2.241	-1.991
17450.	3.32	1.46	1.015	177.9	.014	2.250	-1.839
17650.	3.52	1.94	1.019	180.8	.019	2.257	-1.716
17750.	3.72	2.47	1.025	182.7	.024	2.262	-1.613
17900.	3.92	2.97	1.030	185.2	.029	2.268	-1.534
18050.	4.12	3.47	1.035	187.6	.034	2.273	-1.467
18125.	4.32	4.01	1.040	189.4	.039	2.277	-1.405
18200.	4.52	4.55	1.045	191.2	.044	2.281	-1.352
18275.	4.72	5.08	1.051	192.9	.050	2.285	-1.305
18300.	4.92	5.64	1.055	194.2	.055	2.288	-1.260
18350.	5.12	6.19	1.062	195.8	.060	2.292	-1.221
18350.	5.32	6.77	1.068	196.8	.065	2.294	-1.184
18300.	5.52	7.36	1.074	197.4	.071	2.295	-1.149
18250.	5.72	7.95	1.080	197.9	.077	2.297	-1.116
18075.	5.92	8.61	1.086	197.2	.083	2.295	-1.083
17700.	6.13	9.38	1.094	194.5	.090	2.289	-1.047

EXTRUSION NUMBER 3331
(PLASTIC STRAIN)

LOAD LBS.	CHART ELONG. INS.	ENG. STRAIN %	1+E	TRUE STRESS KSI	TRUE STRAIN	LOG10 STRESS	LOG10 STRAIN
15700.	2.18	.40	1.004	165.7	.004	2.219	-2.401
15900.	2.37	.87	1.009	168.6	.009	2.227	-2.064
16250.	2.56	1.23	1.013	173.0	.013	2.238	-1.896
16400.	2.77	1.82	1.018	175.6	.018	2.244	-1.743
16500.	2.97	2.36	1.024	177.6	.023	2.249	-1.632
16700.	3.17	2.85	1.029	180.5	.028	2.257	-1.550
16800.	3.37	3.39	1.034	182.5	.033	2.262	-1.477
16900.	3.57	3.93	1.039	184.7	.039	2.266	-1.414
17000.	3.77	4.46	1.045	186.7	.044	2.271	-1.360
17100.	3.97	5.00	1.050	188.8	.049	2.276	-1.312
17150.	4.17	5.55	1.055	190.3	.054	2.279	-1.268
17200.	4.37	6.10	1.061	191.9	.059	2.283	-1.227
17200.	4.57	6.68	1.067	192.9	.065	2.285	-1.190
17200.	4.77	7.25	1.072	193.9	.070	2.288	-1.155
17200.	4.97	7.82	1.078	195.0	.075	2.290	-1.123
16700.	5.08	8.32	1.083	190.2	.080	2.279	-1.097

EXTRUSION NUMBER 3246
(PLASTIC STRAIN)

LOAD LBS.	CHART ELONG. INS.	ENG. STRAIN %	1+E	TRUE STRESS KSI	TRUE STRAIN	LOG10 STRESS	LOG10 STRAIN
12700.	2.10	.09	1.001	130.5	.001	2.116	-3.068
12700.	2.21	.40	1.004	131.0	.004	2.117	-2.399
12800.	2.41	.93	1.009	132.8	.009	2.123	-2.036
12870.	2.61	1.46	1.015	134.2	.015	2.128	-1.837
12900.	2.81	2.02	1.020	135.2	.020	2.131	-1.698
12970.	3.01	2.56	1.026	136.7	.025	2.136	-1.597
13000.	3.21	3.12	1.031	137.8	.031	2.139	-1.512
13010.	3.41	3.69	1.037	138.6	.036	2.142	-1.441
13070.	3.61	4.23	1.042	140.0	.041	2.146	-1.383
13080.	3.81	4.80	1.048	140.9	.047	2.149	-1.329
13080.	4.01	5.37	1.054	141.6	.052	2.151	-1.281
13080.	4.21	5.94	1.059	142.4	.058	2.154	-1.239
13075.	4.41	6.52	1.065	143.1	.063	2.156	-1.200
13050.	4.61	7.10	1.071	143.5	.069	2.157	-1.164
13013.	4.81	7.69	1.077	144.0	.074	2.158	-1.130
13000.	5.01	8.27	1.083	144.5	.079	2.160	-1.100
12280.	5.91	11.18	1.112	140.3	.106	2.147	-.975
10500.	6.83	14.64	1.146	123.7	.137	2.092	-.864

EXTRUSION NUMBER 3431
(PLASTIC STRAIN)

LOAD LBS.	CHART ELONG. INS.	ENG. STRAIN %	1+E	TRUE STRESS KSI	TRUE STRAIN	LOG10 STRESS	LOG10 STRAIN
14000.	2.16	.05	1.001	143.9	.001	2.158	-3.288
14200.	2.31	.39	1.004	146.5	.004	2.156	-2.406
14700.	2.53	.80	1.008	152.3	.008	2.183	-2.097
14800.	2.73	1.33	1.013	154.1	.013	2.188	-1.878
14900.	2.95	1.92	1.019	156.0	.019	2.193	-1.721
14950.	3.15	2.47	1.025	157.4	.024	2.197	-1.613
15000.	3.35	3.02	1.030	158.8	.030	2.201	-1.527
15000.	3.51	3.47	1.035	159.5	.034	2.203	-1.466
15100.	3.77	4.17	1.042	161.6	.041	2.209	-1.388
15190.	3.97	4.71	1.047	163.4	.046	2.213	-1.337
15100.	4.16	5.29	1.053	163.4	.052	2.213	-1.288
15100.	4.36	5.85	1.059	164.3	.057	2.216	-1.244
15100.	4.58	6.49	1.065	165.2	.063	2.218	-1.201
15100.	4.88	7.35	1.073	166.6	.071	2.222	-1.149
15000.	5.37	8.79	1.088	167.7	.084	2.225	-1.074
14800.	5.86	10.29	1.103	167.7	.098	2.225	-1.009
14400.	6.17	11.35	1.113	164.8	.107	2.217	-.969
14000.	6.40	12.18	1.122	161.4	.115	2.208	-.940
13100.	6.75	13.57	1.135	152.9	.127	2.184	-.895

EXTRUSION NUMBER 3169
(PLASTIC STRAIN)

LOAD LBS.	CHART ELONG. INS.	ENG. STRAIN %	1+E	TRUE STRESS KSI	TRUE STRAIN	LOG10 STRESS	LOG10 STRAIN
12700.	2.10	.23	1.002	134.6	.002	2.129	-2.637
12600.	2.23	.65	1.006	134.1	.006	2.127	-2.190
12610.	2.51	1.44	1.014	135.3	.014	2.131	-1.843
12520.	2.91	2.58	1.026	135.9	.025	2.136	-1.593
12650.	3.20	3.40	1.034	138.3	.033	2.141	-1.476
12700.	3.40	3.95	1.039	139.6	.039	2.145	-1.412
12700.	3.61	4.55	1.045	140.4	.044	2.147	-1.352
12700.	3.80	5.09	1.051	141.1	.050	2.150	-1.304
12700.	4.00	5.66	1.057	141.9	.055	2.152	-1.259
12680.	4.20	6.25	1.062	142.5	.061	2.154	-1.218
12650.	4.40	6.83	1.068	142.9	.066	2.155	-1.180
12590.	4.60	7.43	1.074	143.0	.072	2.155	-1.145
12490.	4.81	8.08	1.081	142.7	.078	2.155	-1.110
12300.	5.51	10.17	1.102	143.3	.097	2.156	-1.014
9700.	6.54	14.29	1.143	117.2	.134	2.069	-.874

EXTRUSION NUMBER 3235
(PLASTIC STRAIN)

LOAD LBS.	CHART ELONG. INS.	ENG. STRAIN %	1+E	TRUE STRESS KSI	TRUE STRAIN	LOG10 STRESS	LOG10 STRAIN
12500.	1.69	.01	1.000	127.0	.000	2.104	-4.146
13450.	1.84	.07	1.001	136.7	.001	2.136	-3.159
14100.	2.25	.99	1.010	144.7	.010	2.160	-2.006
14300.	2.46	1.51	1.015	147.5	.015	2.169	-1.823
14400.	2.65	2.02	1.020	149.3	.020	2.174	-1.699
14450.	2.87	2.63	1.026	150.7	.026	2.178	-1.586
14450.	3.06	3.17	1.032	151.5	.031	2.180	-1.505
14450.	3.26	3.74	1.037	152.3	.037	2.183	-1.435
14450.	3.46	4.32	1.043	153.2	.042	2.185	-1.374
14450.	3.66	4.89	1.049	154.0	.048	2.187	-1.321
14500.	4.33	6.79	1.068	157.3	.066	2.197	-1.183
14500.	5.50	10.13	1.101	162.2	.097	2.210	-1.015
14200.	5.76	10.99	1.110	160.1	.104	2.204	-.982
14000.	5.96	11.64	1.116	158.8	.110	2.201	-.958
12750.	6.53	13.75	1.138	147.4	.129	2.168	-.890
12700.	6.60	13.97	1.140	147.1	.131	2.168	-.883

EXTRUSION NUMBER 3239
(PLASTIC STRAIN)

LOAD LBS.	CHART ELONG. INS.	ENG. STRAIN %	1+E	TRUE STRESS KSI	TRUE STRAIN	LOG10 STRESS	LOG10 STRAIN
11100.	1.94	.35	1.003	123.4	.003	2.091	-2.457
11290.	2.14	.83	1.008	125.1	.008	2.101	-2.081
11390.	2.35	1.39	1.014	127.9	.014	2.107	-1.861
11410.	2.55	1.95	1.019	128.9	.019	2.110	-1.714
11500.	2.74	2.45	1.025	130.5	.024	2.116	-1.616
11550.	2.94	3.00	1.030	131.8	.030	2.120	-1.529
11600.	3.14	3.55	1.035	133.1	.035	2.124	-1.458
11610.	3.34	4.12	1.041	133.9	.040	2.127	-1.394
11680.	3.54	4.65	1.047	135.4	.045	2.132	-1.342
11700.	3.73	5.19	1.052	136.4	.051	2.135	-1.296
11710.	3.94	5.78	1.058	137.2	.056	2.137	-1.250
11730.	4.13	6.32	1.063	138.2	.061	2.140	-1.213
11730.	4.34	6.92	1.069	139.0	.067	2.143	-1.175
11730.	4.54	7.49	1.075	139.7	.072	2.145	-1.141
11700.	4.74	8.08	1.081	140.1	.078	2.146	-1.110
11600.	5.14	9.27	1.093	140.4	.089	2.147	-1.052
11400.	5.54	10.51	1.105	139.6	.100	2.145	-1.000
11010.	5.94	11.83	1.118	136.4	.112	2.135	-.951
8800.	7.14	16.30	1.163	113.4	.151	2.055	-.821

EXTRUSION NUMBER 3241
(PLASTIC STRAIN)

LOAD LBS.	CHART ELONG. INS.	ENG. STRAIN %	1+E	TRUE STRESS KSI	TRUE STRAIN	LOG10 STRESS	LOG10 STRAIN
12680.	2.09	.21	1.002	132.8	.002	2.123	-2.676
12800.	2.29	.73	1.007	134.8	.007	2.130	-2.139
12880.	2.51	1.32	1.013	136.4	.013	2.135	-1.882
12950.	2.70	1.83	1.018	137.9	.018	2.139	-1.741
13000.	2.90	2.38	1.024	139.1	.024	2.143	-1.628
13080.	3.10	2.92	1.029	140.7	.029	2.148	-1.541
13110.	3.29	3.45	1.034	141.8	.034	2.152	-1.470
13120.	3.49	4.02	1.040	142.7	.039	2.154	-1.405
13120.	3.69	4.59	1.046	143.4	.045	2.157	-1.348
13100.	3.90	5.20	1.052	144.1	.051	2.159	-1.295
13080.	4.09	5.75	1.057	144.6	.056	2.160	-1.253
13000.	4.28	6.33	1.063	144.5	.061	2.160	-1.212
12800.	4.68	7.56	1.076	143.9	.073	2.158	-1.137
11100.	5.95	11.97	1.120	123.9	.113	2.114	-.947

EXTRUSION NUMBER 3243
(PLASTIC STRAIN)

LOAD LBS.	CHART ELONG. INS.	ENG. STRAIN %	1+E	TRUE STRESS KSI	TRUE STRAIN	LOG10 STRESS	LOG10 STRAIN
11800.	1.98	.09	1.001	127.8	.001	2.107	-3.025
12100.	2.10	.30	1.003	131.3	.003	2.118	-2.529
12250.	2.30	.80	1.008	133.6	.008	2.126	-2.100
12310.	2.50	1.34	1.013	135.0	.013	2.130	-1.875
12400.	2.70	1.87	1.019	136.7	.019	2.136	-1.732
12430.	2.90	2.43	1.024	137.8	.024	2.139	-1.620
12510.	3.10	2.96	1.030	139.4	.029	2.144	-1.535
12550.	3.30	3.52	1.035	140.5	.035	2.148	-1.462
12600.	3.50	4.06	1.041	141.9	.040	2.152	-1.400
12600.	3.70	4.64	1.046	142.7	.045	2.154	-1.344
12600.	3.90	5.21	1.052	143.5	.051	2.157	-1.294
12580.	4.20	6.08	1.061	144.4	.059	2.160	-1.229
12500.	4.50	6.97	1.070	144.7	.067	2.160	-1.171
12200.	4.90	8.26	1.083	142.9	.079	2.155	-1.101
10900.	5.90	11.73	1.117	131.8	.111	2.120	-.955

EXTRUSION NUMBER 3234
(PLASTIC STRAIN)

LOAD LBS.	CHART ELONG. INS.	ENG. STRAIN %	1+E	TRUE STRESS KSI	TRUE STRAIN	LOG10 STRESS	LOG10 STRAIN
12000.	2.00	.02	1.000	124.0	.000	2.094	-3.641
12400.	2.21	.43	1.004	128.7	.004	2.110	-2.364
12500.	2.40	.93	1.009	130.4	.009	2.115	-2.034
12580.	2.61	1.49	1.015	131.9	.015	2.120	-1.829
12600.	2.79	2.00	1.020	132.8	.020	2.123	-1.704
12620.	3.01	2.62	1.026	133.8	.025	2.127	-1.588
12580.	3.21	3.16	1.032	135.2	.031	2.131	-1.507
12590.	3.40	3.70	1.037	136.0	.036	2.134	-1.440
12960.	3.61	4.17	1.042	139.5	.041	2.145	-1.389
12690.	3.80	4.84	1.048	137.5	.047	2.138	-1.325
12680.	4.00	5.42	1.054	138.1	.053	2.140	-1.278
12600.	4.30	6.32	1.063	138.4	.061	2.141	-1.213
12400.	4.80	7.84	1.078	138.2	.075	2.141	-1.122
12200.	5.01	8.54	1.085	136.8	.082	2.136	-1.087
10700.	6.00	12.08	1.121	123.9	.114	2.093	-.943

EXTRUSION NUMBER 3167
(PLASTIC STRAIN)

LOAD LBS.	CHART ELONG. INS.	ENG. STRAIN %	1+E	TRUE STRESS KSI	TRUE STRAIN	LOG10 STRESS	LOG10 STRAIN
12500.	1.75	.10	1.001	128.9	.001	2.110	-2.983
12700.	1.95	.64	1.006	130.6	.006	2.116	-2.197
12800.	2.15	1.17	1.012	132.3	.012	2.122	-1.934
12900.	2.35	1.70	1.017	134.1	.017	2.127	-1.772
13000.	2.55	2.24	1.022	135.8	.022	2.133	-1.655
13100.	2.75	2.77	1.028	137.6	.027	2.138	-1.564
13200.	2.95	3.30	1.033	139.3	.032	2.144	-1.488
13200.	3.15	3.87	1.039	140.1	.038	2.146	-1.420
13200.	3.35	4.45	1.044	140.9	.044	2.149	-1.361
13200.	3.55	5.02	1.050	141.6	.049	2.151	-1.310
13100.	3.75	5.63	1.056	141.4	.055	2.150	-1.261
13100.	3.95	6.20	1.062	142.2	.060	2.153	-1.221
13000.	4.15	6.81	1.068	141.9	.066	2.152	-1.181
12800.	4.35	7.46	1.075	140.5	.072	2.148	-1.143
11500.	5.38	10.87	1.109	131.4	.103	2.119	-.986

EXTRUSION NUMBER 3174
(PLASTIC STRAIN)

LOAD LBS.	CHART ELONG. INS.	ENG. STRAIN %	1+E	TRUE STRESS KSI	TRUE STRAIN	LOG10 STRESS	LOG10 STRAIN
12700.	2.12	.25	1.003	130.1	.003	2.114	-2.600
12700.	2.33	.85	1.009	130.9	.008	2.117	-2.071
12700.	2.53	1.42	1.014	131.5	.014	2.119	-1.849
12750.	2.13	.26	1.003	130.6	.003	2.116	-2.590
12750.	2.93	2.55	1.025	133.6	.025	2.126	-1.600
12750.	3.13	3.12	1.031	134.3	.031	2.128	-1.513
12800.	3.33	3.67	1.037	135.6	.035	2.132	-1.444
12800.	3.53	4.24	1.042	136.3	.042	2.135	-1.382
12800.	3.73	4.81	1.048	137.1	.047	2.137	-1.328
12800.	3.93	5.38	1.054	137.8	.052	2.139	-1.280
12800.	4.13	5.95	1.060	138.5	.058	2.142	-1.238
12800.	4.33	6.53	1.065	139.3	.063	2.144	-1.199
12800.	4.53	7.10	1.071	140.1	.069	2.146	-1.164
12800.	4.73	7.67	1.077	140.8	.074	2.149	-1.131
12800.	4.93	8.24	1.082	141.6	.079	2.151	-1.101
12800.	5.13	8.81	1.088	142.3	.084	2.153	-1.073
12600.	5.33	9.48	1.095	140.9	.091	2.149	-1.043
12400.	5.53	10.14	1.101	139.6	.097	2.145	-1.015
10000.	6.92	15.22	1.152	117.7	.142	2.071	-.849

EXTRUSION NUMBER 3475
(PLASTIC STRAIN)

LOAD LBS.	CHART ELONG. INS.	ENG. STRAIN %	1+E	TRUE STRESS KSI	TRUE STRAIN	LOG10 STRESS	LOG10 STRAIN
14400.	2.31	.02	1.000	143.1	.000	2.156	-3.766
14790.	2.51	.41	1.004	147.5	.004	2.169	-2.387
15000.	2.73	.94	1.009	150.4	.009	2.177	-2.027
15100.	2.99	1.64	1.016	152.5	.016	2.183	-1.788
15200.	3.21	2.23	1.022	154.4	.022	2.189	-1.657
15220.	3.41	2.79	1.028	155.4	.027	2.191	-1.561
15290.	3.61	3.33	1.033	157.0	.033	2.196	-1.485
15300.	3.81	3.90	1.039	157.9	.038	2.198	-1.418
15320.	4.11	4.74	1.047	159.4	.046	2.203	-1.334
15350.	4.31	5.30	1.053	160.5	.052	2.206	-1.287
15350.	4.52	5.90	1.059	161.5	.057	2.208	-1.241
15350.	4.70	6.42	1.064	162.3	.062	2.210	-1.206
15350.	4.91	7.02	1.070	163.2	.068	2.213	-1.169
15350.	5.11	7.59	1.076	164.1	.073	2.215	-1.136
15300.	5.30	8.16	1.082	164.4	.078	2.216	-1.106
15300.	5.60	9.01	1.090	165.7	.086	2.219	-1.064
15200.	5.92	9.98	1.100	166.1	.095	2.220	-1.022
15000.	6.04	10.41	1.104	164.5	.099	2.216	-1.004
14400.	6.88	13.09	1.131	161.8	.123	2.209	-.910
12000.	7.84	16.93	1.169	139.4	.156	2.144	-.806

EXTRUSION NUMBER 3241
(CORRECTED TOTAL STRAIN)

LOAD LBS.	CHART ELONG. INS.	ENG. STRAIN %	1+E	TRUE STRESS KSI	TRUE STRAIN	LOG10 STRESS	LOG10 STRAIN
12500.	2.00	.83	1.008	131.7	.008	2.120	-2.084
12700.	2.10	1.04	1.010	134.1	.010	2.128	-1.987
12750.	2.20	1.30	1.013	135.0	.013	2.130	-1.888
12800.	2.30	1.57	1.016	135.9	.016	2.133	-1.808
12850.	2.40	1.83	1.018	136.8	.018	2.136	-1.740
12900.	2.50	2.10	1.021	137.7	.021	2.139	-1.682
12950.	2.60	2.37	1.024	138.6	.023	2.142	-1.631
12975.	2.70	2.64	1.026	139.2	.026	2.144	-1.583
12990.	2.80	2.92	1.029	139.8	.029	2.145	-1.540
13010.	2.90	3.20	1.032	140.4	.032	2.147	-1.501
13025.	3.00	3.48	1.035	140.9	.034	2.149	-1.466
13050.	3.10	3.76	1.038	141.5	.037	2.151	-1.433
13075.	3.20	4.03	1.040	142.2	.040	2.153	-1.403
13100.	3.30	4.31	1.043	142.8	.042	2.155	-1.375
13125.	3.40	4.59	1.046	143.5	.045	2.157	-1.348
13150.	3.50	4.86	1.049	144.1	.047	2.159	-1.323
13150.	3.60	5.15	1.051	144.5	.050	2.160	-1.299
13150.	3.70	5.44	1.054	144.9	.053	2.161	-1.276
13150.	3.80	5.72	1.057	145.3	.056	2.162	-1.255
13125.	3.90	6.02	1.060	145.5	.058	2.163	-1.233
13100.	4.00	6.31	1.063	145.6	.061	2.163	-1.213
13075.	4.10	6.61	1.066	145.7	.064	2.163	-1.194
13050.	4.20	6.90	1.069	145.8	.067	2.164	-1.175
13025.	4.30	7.20	1.072	146.0	.070	2.164	-1.158
12975.	4.40	7.51	1.075	145.8	.072	2.164	-1.140
12925.	4.50	7.81	1.078	145.7	.075	2.163	-1.124
12875.	4.60	8.12	1.081	145.5	.078	2.163	-1.108
12825.	4.70	8.42	1.084	145.4	.081	2.162	-1.092
12725.	4.80	8.75	1.087	144.7	.084	2.160	-1.076

EXTRUSION NUMBER 3167
(CORRECTED TOTAL STRAIN)

LOAD LBS.	CHART ELONG. INS.	ENG. STRAIN %	1+E	TRUE STRESS KSI	TRUE STRAIN	LOG10 STRESS	LOG10 STRAIN
11900.	1.55	.54	1.005	122.3	.005	2.087	-2.268
12400.	1.65	.66	1.007	127.5	.007	2.106	-2.179
12600.	1.75	.88	1.009	129.9	.009	2.114	-2.055
12700.	1.85	1.14	1.011	131.2	.011	2.118	-1.946
12700.	1.95	1.42	1.014	131.6	.014	2.119	-1.850
12750.	2.05	1.69	1.017	132.5	.017	2.122	-1.775
12800.	2.15	1.96	1.020	133.4	.019	2.125	-1.711
12850.	2.25	2.23	1.022	134.2	.022	2.128	-1.656
12900.	2.35	2.50	1.025	135.1	.025	2.131	-1.607
12950.	2.45	2.77	1.028	136.0	.027	2.134	-1.563
13000.	2.55	3.04	1.030	136.9	.030	2.136	-1.523
13050.	2.65	3.31	1.033	137.8	.033	2.139	-1.487
13050.	2.75	3.60	1.036	138.1	.035	2.140	-1.452
13050.	2.85	3.88	1.039	138.5	.038	2.142	-1.419
13100.	2.95	4.15	1.042	139.4	.041	2.144	-1.391
13150.	3.05	4.42	1.044	140.3	.043	2.147	-1.364
13150.	3.15	4.71	1.047	140.7	.046	2.148	-1.337
13150.	3.25	4.99	1.050	141.1	.049	2.149	-1.312
13150.	3.35	5.28	1.053	141.5	.051	2.151	-1.289
13150.	3.45	5.57	1.056	141.8	.054	2.152	-1.266
13150.	3.55	5.85	1.059	142.2	.057	2.153	-1.245
13150.	3.65	6.14	1.061	142.6	.060	2.154	-1.225
13150.	3.75	6.42	1.064	143.0	.062	2.155	-1.206
13150.	3.85	6.71	1.067	143.4	.065	2.156	-1.187
13150.	3.95	7.00	1.070	143.8	.068	2.158	-1.170
13100.	4.05	7.30	1.073	143.6	.070	2.157	-1.152
13000.	4.15	7.62	1.076	143.0	.073	2.155	-1.134
12950.	4.25	7.92	1.079	142.8	.076	2.155	-1.118
12800.	4.35	8.25	1.083	141.6	.079	2.151	-1.101

EXTRUSION NUMBER 3234
(CORRECTED TOTAL STRAIN)

LOAD LBS.	CHART ELONG. INS.	ENG. STRAIN %	1+E	TRUE STRESS KSI	TRUE STRAIN	LOG10 STRESS	LOG10 STRAIN
12300.	2.10	.94	1.009	128.3	.009	2.108	-2.030
12400.	2.20	1.18	1.012	129.7	.012	2.113	-1.930
12450.	2.30	1.45	1.014	130.5	.014	2.116	-1.843
12500.	2.40	1.71	1.017	131.4	.017	2.119	-1.770
12550.	2.50	1.98	1.020	132.3	.020	2.121	-1.708
12575.	2.60	2.25	1.023	132.9	.022	2.123	-1.652
12600.	2.70	2.53	1.025	133.5	.025	2.126	-1.602
12615.	2.80	2.81	1.028	134.0	.028	2.127	-1.557
12625.	2.90	3.09	1.031	134.5	.030	2.129	-1.517
12640.	3.00	3.37	1.034	135.0	.033	2.130	-1.479
12650.	3.10	3.65	1.037	135.5	.036	2.132	-1.445
12675.	3.20	3.93	1.039	136.1	.039	2.134	-1.414
12700.	3.30	4.20	1.042	136.8	.041	2.136	-1.385
12700.	3.40	4.49	1.045	137.1	.044	2.137	-1.357
12700.	3.50	4.78	1.048	137.5	.047	2.138	-1.331
12700.	3.60	5.06	1.051	137.9	.049	2.140	-1.306
12700.	3.70	5.35	1.053	138.3	.052	2.141	-1.283
12700.	3.80	5.63	1.056	138.6	.055	2.142	-1.261
12700.	3.90	5.92	1.059	139.0	.058	2.143	-1.240
12675.	4.00	6.22	1.062	139.1	.060	2.143	-1.220
12650.	4.10	6.51	1.065	139.2	.063	2.144	-1.200
12625.	4.20	6.81	1.068	139.4	.066	2.144	-1.181
12600.	4.30	7.11	1.071	139.5	.069	2.144	-1.163
12575.	4.40	7.40	1.074	139.6	.071	2.145	-1.146
12550.	4.50	7.70	1.077	139.7	.074	2.145	-1.130
12500.	4.60	8.00	1.080	139.5	.077	2.145	-1.113
12450.	4.70	8.31	1.083	139.4	.080	2.144	-1.098
12400.	4.80	8.62	1.086	139.2	.083	2.144	-1.083
12300.	4.90	8.94	1.089	138.5	.086	2.141	-1.067
12200.	5.00	9.27	1.093	137.8	.089	2.139	-1.052
12100.	5.10	9.60	1.096	137.1	.092	2.137	-1.038
12000.	5.20	9.93	1.099	136.3	.095	2.135	-1.024
11900.	5.30	10.25	1.103	135.6	.098	2.132	-1.010

EXTRUSION NUMBER 3235
(CORRECTED TOTAL STRAIN)

LOAD LBS.	CHART ELONG. INS.	ENG. STRAIN %	1+E	TRUE STRESS KSI	TRUE STRAIN	LOG10 STRESS	LOG10 STRAIN
12800.	1.75	.85	1.009	131.2	.008	2.118	-2.072
13300.	1.85	.97	1.010	136.4	.010	2.135	-2.013
13700.	1.95	1.13	1.011	140.8	.011	2.149	-1.949
13850.	2.05	1.37	1.014	142.6	.014	2.154	-1.867
14100.	2.15	1.57	1.016	145.5	.016	2.163	-1.807
14200.	2.25	1.83	1.018	146.9	.018	2.167	-1.742
14200.	2.35	2.11	1.021	147.3	.021	2.168	-1.680
14300.	2.45	2.37	1.024	148.7	.023	2.172	-1.631
14400.	2.55	2.62	1.026	150.1	.026	2.176	-1.587
14450.	2.65	2.89	1.029	151.1	.028	2.179	-1.545
14500.	2.75	3.16	1.032	152.0	.031	2.182	-1.507
14500.	2.85	3.45	1.034	152.4	.034	2.183	-1.470
14500.	2.95	3.73	1.037	152.8	.037	2.184	-1.436
14550.	3.05	4.00	1.040	153.7	.039	2.187	-1.405
14550.	3.15	4.29	1.043	154.2	.042	2.188	-1.377
14550.	3.25	4.57	1.046	154.6	.045	2.189	-1.350
14550.	3.35	4.86	1.049	155.0	.047	2.190	-1.324
14550.	3.45	5.15	1.051	155.4	.050	2.192	-1.300
14550.	3.55	5.43	1.054	155.9	.053	2.193	-1.277
14550.	3.65	5.72	1.057	156.3	.056	2.194	-1.255
14550.	3.75	6.00	1.060	156.7	.058	2.195	-1.234
14600.	3.85	6.27	1.063	157.6	.061	2.198	-1.216
14600.	3.95	6.56	1.066	158.1	.064	2.199	-1.197
14600.	4.05	6.84	1.068	158.5	.066	2.200	-1.179
14600.	4.15	7.13	1.071	158.9	.069	2.201	-1.162
14600.	4.25	7.42	1.074	159.3	.072	2.202	-1.145
14600.	4.35	7.70	1.077	159.8	.074	2.203	-1.130
14600.	4.45	7.99	1.080	160.2	.077	2.205	-1.114
14600.	4.55	8.27	1.083	160.6	.080	2.206	-1.100
14600.	4.65	8.56	1.086	161.0	.082	2.207	-1.085
14600.	4.75	8.85	1.088	161.5	.085	2.208	-1.072
14600.	4.85	9.13	1.091	161.9	.087	2.209	-1.059
14600.	4.95	9.42	1.094	162.3	.090	2.210	-1.046
14600.	5.05	9.70	1.097	162.7	.093	2.211	-1.033
14550.	5.15	10.01	1.100	162.6	.095	2.211	-1.021
14500.	5.25	10.31	1.103	162.5	.098	2.211	-1.008
14500.	5.35	10.60	1.106	162.9	.101	2.212	-.997
14500.	5.45	10.88	1.109	163.4	.103	2.213	-.985
14450.	5.55	11.18	1.112	163.2	.106	2.213	-.975
14400.	5.65	11.49	1.115	163.1	.109	2.212	-.964
14300.	5.75	11.80	1.118	162.4	.112	2.211	-.952

EXTRUSION NUMBER 3169
(CORRECTED TOTAL STRAIN)

LOAD LBS.	CHART ELONG. INS.	ENG. STRAIN %	1+E	TRUE STRESS KSI	TRUE STRAIN	LOG10 STRESS	LOG10 STRAIN
12700.	2.00	.76	1.008	135.3	.008	2.131	-2.122
12900.	2.10	.97	1.010	137.7	.010	2.139	-2.017
12700.	2.20	1.33	1.013	136.1	.013	2.134	-1.879
12650.	2.30	1.64	1.016	136.0	.016	2.133	-1.790
12650.	2.40	1.92	1.019	136.3	.019	2.135	-1.720
12625.	2.50	2.22	1.022	136.5	.022	2.135	-1.659
12625.	2.60	2.50	1.025	136.8	.025	2.136	-1.607
12625.	2.70	2.79	1.028	137.2	.028	2.137	-1.560
12650.	2.80	3.07	1.031	137.9	.030	2.139	-1.520
12675.	2.90	3.34	1.033	138.5	.033	2.141	-1.483
12675.	3.00	3.63	1.036	138.9	.036	2.143	-1.448
12700.	3.10	3.90	1.039	139.5	.038	2.145	-1.417
12700.	3.20	4.19	1.042	139.9	.041	2.146	-1.387
12700.	3.30	4.48	1.045	140.3	.044	2.147	-1.359
12700.	3.40	4.76	1.048	140.7	.047	2.148	-1.332
12700.	3.50	5.05	1.050	141.1	.049	2.149	-1.308
12725.	3.60	5.32	1.053	141.7	.052	2.151	-1.285
12725.	3.70	5.61	1.056	142.1	.055	2.153	-1.263
12725.	3.80	5.90	1.059	142.5	.057	2.154	-1.242
12725.	3.90	6.18	1.062	142.9	.060	2.155	-1.222
12725.	4.00	6.47	1.065	143.3	.063	2.156	-1.203
12725.	4.10	6.75	1.068	143.6	.065	2.157	-1.185
12725.	4.20	7.04	1.070	144.0	.068	2.158	-1.167
12700.	4.30	7.34	1.073	144.1	.071	2.159	-1.150
12675.	4.40	7.63	1.076	144.3	.074	2.159	-1.133
12650.	4.50	7.93	1.079	144.4	.076	2.159	-1.117
12650.	4.60	8.21	1.082	144.8	.079	2.161	-1.103
12600.	4.70	8.52	1.085	144.6	.082	2.160	-1.087
12575.	4.80	8.82	1.088	144.7	.084	2.160	-1.073
12525.	4.90	9.12	1.091	144.5	.087	2.160	-1.059
12450.	5.00	9.44	1.094	144.1	.090	2.159	-1.045
12350.	5.10	9.76	1.098	143.3	.093	2.156	-1.031

EXTRUSION NUMBER 3272
(CORRECTED TOTAL STRAIN)

LOAD LBS.	CHART ELONG. INS.	ENG. STRAIN %	1+E	TRUE STRESS KSI	TRUE STRAIN	LOG10 STRESS	LOG10 STRAIN
16380.	3.07	.58	1.006	162.8	.006	2.212	-2.239
16590.	3.17	.76	1.008	165.1	.008	2.218	-2.121
16780.	3.27	.95	1.010	167.3	.009	2.224	-2.024
16900.	3.37	1.18	1.012	168.9	.012	2.228	-1.932
17030.	3.47	1.40	1.014	170.6	.014	2.232	-1.858
17190.	3.57	1.60	1.016	172.5	.016	2.237	-1.798
17300.	3.67	1.83	1.018	174.0	.018	2.241	-1.740
17400.	3.77	2.07	1.021	175.5	.020	2.244	-1.688
17500.	3.87	2.31	1.023	176.9	.023	2.248	-1.642
17590.	3.97	2.55	1.025	178.2	.025	2.251	-1.599
17650.	4.07	2.80	1.028	179.3	.028	2.253	-1.558
17730.	4.17	3.05	1.030	180.5	.030	2.256	-1.522
17800.	4.27	3.30	1.033	181.7	.032	2.259	-1.489
17850.	4.37	3.56	1.036	182.6	.035	2.262	-1.456
17900.	4.47	3.82	1.038	183.6	.038	2.264	-1.426
17950.	4.57	4.08	1.041	184.6	.040	2.266	-1.398
18000.	4.67	4.34	1.043	185.5	.043	2.268	-1.371
18030.	4.77	4.61	1.046	186.3	.045	2.270	-1.346
18100.	4.87	4.87	1.049	187.5	.048	2.273	-1.323
18130.	4.97	5.14	1.051	188.3	.050	2.275	-1.300
18150.	5.07	5.41	1.054	189.0	.053	2.276	-1.278
18200.	5.17	5.67	1.057	190.0	.055	2.279	-1.258
18230.	5.27	5.94	1.059	190.8	.058	2.281	-1.238
18250.	5.37	6.22	1.062	191.5	.060	2.282	-1.219
18250.	5.47	6.51	1.065	192.0	.063	2.283	-1.200
18250.	5.57	6.79	1.068	192.5	.066	2.285	-1.182
18250.	5.67	7.08	1.071	193.1	.068	2.286	-1.165
18250.	5.77	7.36	1.074	193.6	.071	2.287	-1.148
18250.	5.87	7.65	1.077	194.1	.074	2.288	-1.132
18230.	5.97	7.95	1.079	194.4	.076	2.289	-1.117
18200.	6.07	8.25	1.082	194.6	.079	2.289	-1.101
18150.	6.17	8.56	1.086	194.7	.082	2.289	-1.086
18100.	6.27	8.87	1.089	194.7	.085	2.289	-1.071
18000.	6.37	9.21	1.092	194.2	.088	2.288	-1.055
17900.	6.47	9.54	1.095	193.7	.091	2.287	-1.040